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ENERGY DEMO

HOME ENERGY SAVING DEMONSTRATION PROGRAM

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MANITOBA/CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources — oil and natural gas — are becoming less accessible and more costly. However, Canada is well-endowed with renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of Manitoba and Canada entered into a Conservation and Renewable Energy Demonstration Agreement which was signed May 9, 1980 and terminated March 31, 1984. The Agreement was dedicated to the development and demonstration of conservation and renewable energy technologies. Equally cost-shared by the provincial and federal governments, the program had a total budget of $18-million.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- To develop broad public awareness of the potential of renewable energy and conservation technology
- To provide opportunities for the commercial application of the technologies within Manitoba.
- To create economic spin-off benefits for manufacturing, industry and commerce.
- To create employment in new or existing energy-related industries.

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SUMMARY

The Energy Demo program was developed to provide a public demonstration to Manitobans of the potential of residential energy conservation, to acquire information on the capabilities and limitations of the various retrofit alternatives and to offer insight into the understanding by the general public and contractors of energy conservation. Energy Demo was carried out under the Conservation and Renewable Energy Demonstration Agreement between the Government of Canada and the Province of Manitoba. To meet the program goals, 154 privately owned single family, detached houses, of varying size, age and construction were subjected to detailed energy audits which included HOTCAN analyses and airtightness testing. From this group, 83 houses received comprehensive energy conservation retrofits to reduce the total predicted energy usage of each house by a minimum of 40%. The retrofits included the insulation of various building components, air leakage sealing and the replacement of existing heating plants with high efficiency units. Cost of the retrofits ranged up to $10,000 and were shared on a 50/50 basis between the homeowner and the Energy Demo program.

The Energy Demo audits and retrofits indicated that the greatest opportunities for cost-effective reductions in energy consumption were the insulation of low R-value components such as basements and empty wall cavities, air leakage sealing and the installation of high efficiency heating plants. Side benefits which were also indentified included improved comfort levels and increased resale value. Potentially negative side effects included increased property tax assessments and reduced living space areas for some types of retrofits.

The project also identified safety concerns with the establishment and maintenance of acceptable indoor air quality, the provision of sufficient combustion and dilution air to prevent furnace backdrafting and unsafe installation practices for wood-burning appliances.

The quality of workmanship was generally very good. However, homeowners and contractors commonly displayed a poor understanding of the proper design of energy conservation retrofits. In particular, they had difficulty identifying and priorizing the most cost-effective retrofit alternatives. Homeowners were found to be receptive to the energy audit recommendations but were more interested in the qualitative than the quantitative results.

Energy Demo also provided a better understanding of energy audit techniques. In particular, it suggested possible limitations with the use of HOTCAN for analyzing existing houses.

RÉSUMÉ

Le programme Démo Énergie a été mis sur pied pour démontrer au public manitobain le potentiel qui existe en matière de conservation de l'énergie, dans les maisons, pour réunir des renseignements sur les possibilités et les limites de systèmes variés d'amélioration thermique et enfin pour jauger les connaissances du public et des entrepreneurs dans ce domaine. Le projet a été réalisé dans le cadre de l'Entente de démonstration des énergies renouvelables et des économies d'énergie qui a été signée par le gouvernement du Canada et la province du Manitoba. Pour atteindre les objectifs du programme, des vérifications détaillées de consommation d'énergie comprenant des analyses HOTCAN et des mesures d'herméticité à l'air ont été effectuées dans 154 maisons particulières unifamiliales de diverses grandeur, et type de construction. 83 de ces maisons ont fait l'objet de travaux d'amélioration thermique complets afin de réduire d'au moins 40% la consommation totale d'énergie prévue pour chaque maison. Les travaux d'amélioration comprenaient l'installation d'isolant calorifuge à divers endroits, le calfeutrage des fentes et le remplacement des appareils de chauffage existants par des modèles à grand rendement. Le coût des travaux d'amélioration a atteint 10 000 dollars dans certains cas et il a été réparti également entre les propriétaires et Démo Énergie.

Les vérifications effectuées par Démo Énergie ainsi que les travaux d'amélioration ont démontré que les meilleurs moyens de réduire la consommation d'énergie consistaient à isoler les sections ayant une faible valeur R comme les sous-sols et les murs vides, à calfeutrer les fentes et à installer des appareils de chauffage à rendement élevé. Parmi

les avantages secondaires, on a remarqué un accroissement du comfort et une augmentation du prix de revente des maisons. Les résultats secondaires négatifs éventuels sont l'accroissement de l'impôt foncier et, dans le cas de certains travaux, la diminution de l'espace vital à l'intérieur des habitations.

Le projet a également fait ressortir l'aspect sécurité en ce qui concerne :

1) la façon de s'assurer que la qualité de l'air à l'intérieur des logements demeure acceptable;
2) l'entrée d'une quantité suffisante d'air de combustion et d'admission pour éviter le tirage inverti et,
3) l'installation défectueuses d'appareils de chauffage au bois.

En général, la qualité du travail effectué a été très bonne. Toutefois, la plupart des propriétaires et entrepreneurs se sont montrés plutôt ignorants de la conception technique des travaux à effectuer pour conserver l'énergie. Par exemple, ils avaient du mal à décider quelles seraient les améliorations les plus efficaces et selon quel ordre de priorité ils devaient les réaliser. Certains propriétaires ont accueillis favorablement les recommandations formulées après la vérification de leur logement, mais ils se sont plus intéressés à l'aspect qualitatif qu'à l'aspect quantitatif des résultats.

Énergie Démo a permis également de mieux comprendre les méthodes utilisées pour vérifier la consommation d'énergie. On s'est rendu compte, en particulier, de limitations possibles dans l'emploi des méthodes HOTCAN pour analyser l'état des maisons actuelles.

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SECTION 1
INTRODUCTION

1.1 BACKGROUND

This report has been prepared as a summary of the Manitoba Energy Demo - Home Energy Saving Demonstration Program. Energy Demo was carried out under the Conservation and Renewable Energy Demonstration Agreement (CREDA) between the Government of Canada and the Province of Manitoba and was designed to demonstrate the potential of residential energy conservation alternatives to Manitobans.

The Energy Demo program was developed because of a perceived need for a visible demonstration of residential energy conservation retrofits. While several demonstrations of energy-efficient new construction had taken place, it was felt that a similar project, applicable to existing housing, was needed.

1.2 PURPOSE AND SCOPE

The objectives of the Energy Demo program were:

1. To provide a public demonstration of residential energy conservation retrofit alternatives.

2. To evaluate and document the technical, economic and practical aspects of residential energy conservation as applied to Manitoba.

3. To provide information on the understanding, by the general public and contractors, of residential energy conservation.

To meet these objectives, Energy Demo was designed as a once-only project in which a group of 154 privately owned houses were subjected to detailed energy audits. From this group, 83 were selected for comprehensive energy conservation retrofits to reduce the total predicted energy usage of each house by a minimum of 40%.

Energy Demo was not conceived in the belief that the types of retrofits demonstrated in the project represented economic or technical optimums for minimizing energy usage in existing houses. Rather, it was designed to provide the opportunity for a wide range of possible alternatives to be demonstrated and evaluated even if some ultimately proved to be unsatisfactory.

1.3 REPORT STRUCTURE

This report has been structured to reflect the differing interests of its various readers:

- Section 1 provides a brief introduction and background to the program and should be reviewed by all readers.
- Section 2 summarizes the program outline and major events and will primarily be of interest to program planners, managers and administrators.
- Section 3 provides brief descriptions of the project houses and offers, for comparison purposes, a review of the major characteristics of Manitoba residential building stock.
- Section 4 offers a more detailed technical and economic analysis of the various retrofit measures and summarizes many of the related findings. It will be mainly of interest to technical readers.
- Section 5 discusses the residential energy audit procedures used during Energy Demo and offers some comments applicable to similar programs. It should be reviewed by those involved in the technical design of audit procedures.
- Section 6 comments on the apparent understanding of residential energy conservation displayed by the homeowners and contractors who were involved in the Energy Demo program. This section will be of interest to those involved in the transfer of technology to these groups.
- Section 7 briefly reviews how the findings and knowledge gained during the Energy Demo program were transfered to subsequent programs with more universal application. This will be of interest to program planners and managers.

- Section 8 briefly summarizes the major conclusions and recommendations of the Energy Demo program.

A glossary of terms is also included in the main volume of this report.

- Appendix A contains a copy of the Energy Demo program application form.

- Appendix B contains copies of the major forms, checklists, and related technical literature used to perform Energy Demo audits.

- Appendix C contains detailed descriptions of the 83 houses which were retrofitted during the program. Each description also includes a summary of the retrofit performed on that house.

- Appendix D contains detailed descriptions of the 71 houses which received energy audits but were not retrofitted.

SECTION 2
PROGRAM OUTLINE

2.1 INTRODUCTION

This section of the report summarizes the basic organization and outline of the Energy Demo program. It discusses the roles of the various participants, reviews the major stages of the project and provides a historical summary of events.

2.2 PROGRAM ORGANIZATION

Energy Demo was carried out under the Conservation and Renewable Energy Demonstration Agreement. Overall responsibility for its execution rested with a Steering Committee composed of representatives from Energy, Mines and Resources Canada (EMR), and Manitoba Energy & Mines (E & M). Day-to-day program management was the responsibility of E & M. A Consultant Team composed of UNIES Ltd. and Appin Solar Associates Inc. of Winnipeg was retained to assist with the delivery of the program.

2.3 SUMMARY OF EVENTS

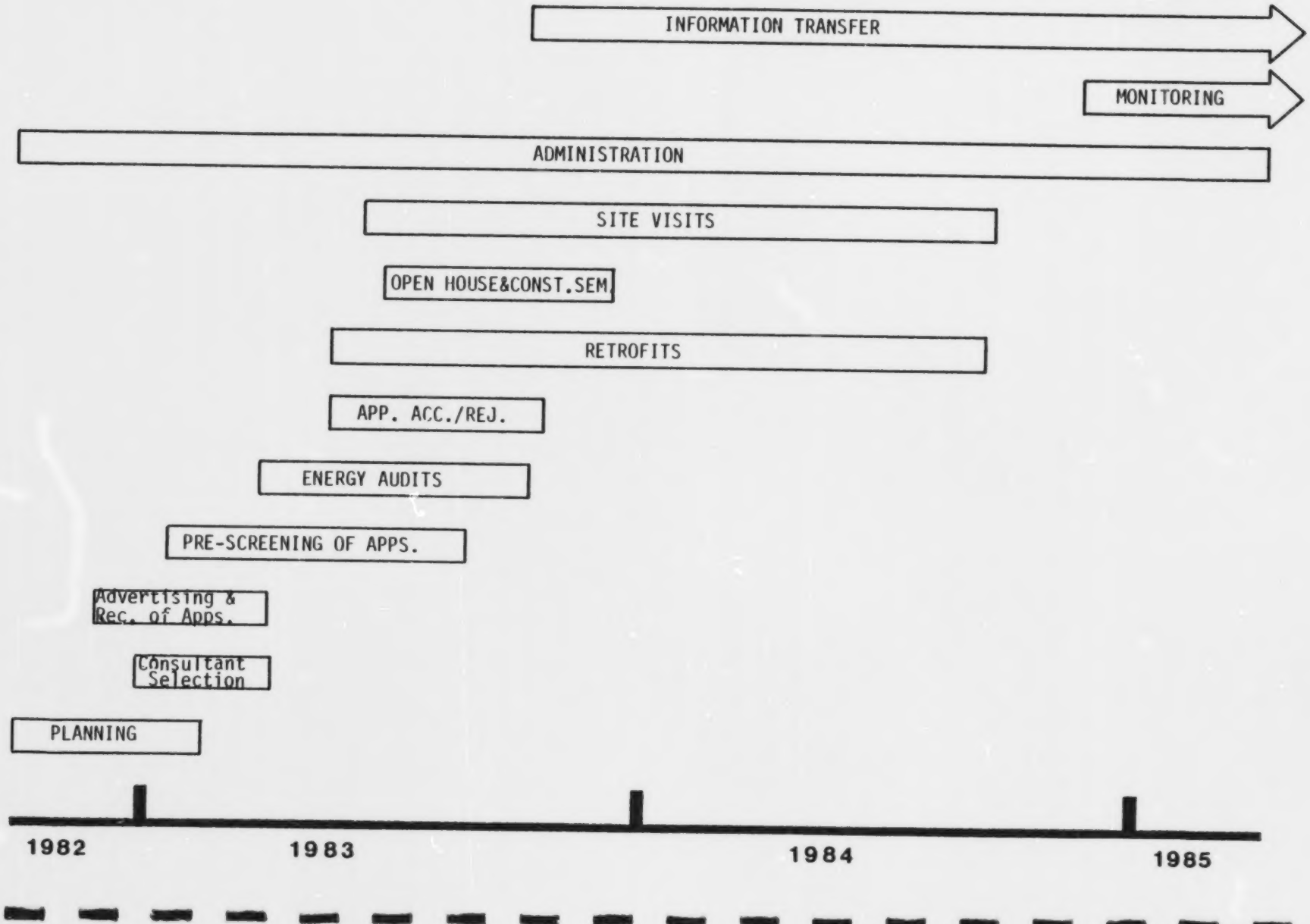
The following description discusses the major stages of the program. These are summarized with a historical time scale in Figure 2.1.

2.3.1 Planning

The need for a residential energy conservation retrofit demonstration in Manitoba had been recognized for some time. The decision to proceed with a formal project was made in the late fall of 1982 by EMR and E & M. During the course of several discussions, the major details relating to project objectives, scope and time frame were identified. Although several types of demonstration programs were considered, it was decided that the most appropriate would be a once-only program in which actual, privately owned houses were retrofitted using measures proposed by their owners. To qualify, the retrofits were required to produce

FIGURE 2.1

ENERGY DEMO, SUMMARY OF EVENTS



substantial reductions in energy use while being relatively cost effective. To permit a wide range of conservation alternatives to be explored, the program cost-shared the retrofits with the homeowners. To qualify, the retrofit proposals had to meet the following selection criteria:

- o The retrofit had to produce a minimum reduction of 40% in the total predicted energy use of the home. Energy use was defined as the space heating, domestic hot water heating (DHW) and appliance energy use.
- o The predicted post-retrofit energy consumption could not exceed 250 kWh/m² per year based on total floor area (including the basement and any addition to the floor space which occurred as part of the retrofit).
- o The retrofit had to be as cost effective as possible.
- o The total retrofit cost had to be between $2,000 and $10,000. Cost of the retrofit was shared on a 50/50 basis between the homeowner and the program.
- o The market value of the home and land could not exceed $64,000.
- o The home had to be the principal residence of the owner.
- o The home must have been constructed before December 31, 1970.
- o Houses would be selected to provide a representative distribution with respect to age, size and type.
- o The home had to be a detached single family dwelling.
- o The homeowners had to agree to permit a limited number of pre-arranged public visits to their home.
- o Homeowners had to agree to permit their home's energy consumption to be monitored for two years after completion of the retrofit.
- o The allocation of retrofitted houses around the province would reflect the population distribution.
- o Preference would be given to commercially performed retrofits to enhance the job creation aspects of the program.

The intent of the selection criteria was to permit a representative cross-section of Manitoba housing stock to be included in the program.

To permit maximum innovation from homeowners and their contractors, the program requirements were deliberately structured as a performance and not a prescriptive standard. Although technical information and literature was provided to guide homeowners, creative solutions to meeting the energy performance criteria were encouraged.

To determine if each house and its proposed retrofit met the program requirements, a detailed energy audit was performed on it. To provide a reasonable sized demonstration, it was decided that approximately 150 houses would be audited. Of these, up to the first 120 which met the requirements would be selected to receive retrofits.

2.3.2 Consultant Selection

The Steering Committee decided to retain the services of a Consultant with experience in residential energy conservation to assist with program delivery. A Request for Proposals was issued in January, 1983. Following receipt and review of submissions, a contract was awarded to a Consultant team composed of UNIES Ltd. and Appin Solar Associates Inc. of Winnipeg as primary contractors and the Saskatchewan Research Council as advisors. The primary responsibilities of the Consultants were to:

- Conduct energy audits on all houses which passed an initial pre-screening by E & M. The audit included a detailed energy analysis of each house and of the proposed retrofit.
- Perform pre-retrofit airtightness tests on all houses which were audited and post-retrofit tests on those which were retrofitted.
- Provide technical input and guidance to the homeowners and their contractors in the design and construction of the retrofit.
- Conduct a series of site visits to all retrofitted houses during the construction phase to monitor the construction of the retrofits and provide any required assistance.
- Participate in Contractors Seminars on retrofitting held during the project.
- Provide a final summary report.

2.3.3 Advertising and Receipt of Applications

To generate applications, province-wide public advertising for the program commenced in December, 1982. The original program deadline was set as February 18, 1983. However since only 148 applications were received by this date, the deadline was extended to March 31, 1983 and additional advertising was carried out. This extension generated an additional 108 applications to bring the total to 256. A copy of the application booklet is attached in Appendix A. The application required the homeowner to provide general information on the house, its size, style of construction, mechanical systems, etc. as well as information on the type and cost of the proposed retrofit.

Retrofit estimates supplied by the homeowner had to be supported with quotations from contractors and suppliers. Applicants were urged to obtain at least two estimates for each major item.

2.3.4 Pre-Screening of Applications

Following the receipt of applications, E & M conducted a pre-screening to make certain the required information had been included in the application and to reject those which were obviously incapable of meeting the program requirements.

2.3.5 Energy Audits

As applications passed the pre-screening, they were turned over to the Consultants who then scheduled and performed the energy audits. Audits were performed by a one or two man team and consisted of the following:

- o Verification that the basic information on the application was correct.
- o A general examination of the house.
- o A review of the application and proposed retrofit with the homeowner.

- o Collection of data to perform a HOTCAN energy analysis on the house and the proposed retrofit.
- o An airtightness test.

These steps were performed on-site and typically took 4 to 8 man-hours plus travel time to complete (the variation was caused by large differences in house size and complexity).

HOTCAN analyses were run on the house and on the proposed retrofit when the audit team returned to the office. Each proposed retrofit measure (such as upgrading wall insulation, replacing windows, air leakage sealing, etc.) was analyzed separately and then in combination with other measures.

In general, the quality of the homeowner proposals, in terms of their ability to meet the program requirements, was much poorer than anticipated. To prevent the rejection rate from soaring, additional input was provided by the Consultants to identify conservation alternatives and combine them in the most cost-effective package. For most cases, retrofit measures and combinations of measures were identified and analyzed which the homeowner had not considered.

Once the analysis had been completed, the Consultant contacted the homeowner by telephone to review the results. In most instances, recommendations were made for changes to the application to enhance its probability of acceptance into the Energy Demo program. Homeowners usually accepted these recommendations. The results of the analysis were then documented and submitted to E & M along with recommendations for acceptance or rejection. Samples of the HOTCAN input forms and the "Retrofit Proposal Evaluation" report are included in Appendix A. A total of 154 houses received energy audits.

2.3.6 Application Acceptance/Rejection

Upon receipt and review of the Consultant's report, E & M evaluated the application and made a decision on its acceptance or rejection. The original application usually had to be re-written by E & M to accommodate the recommended changes.

Discretion was applied in some cases to permit proposals which did not meet the Selection Criteria to be included. This permitted a more diverse range of retrofits to be included in the program. For example, most of the double wall retrofits included were not very cost effective. However, they were accepted in order to provide more information on the applicability of this technique to Manitoba.

Successful applicants were then contacted to verify that they were in agreement with the (in most cases modified) proposal. They were then offered contracts (between the Province of Manitoba and the homeowner) to cost-share the retrofit. Since most of the retrofits had been significantly modified as the result of the energy audit and because many of the original cost quotations were outdated or were not supported with competitive bids, all successful applicants were required to obtain new quotations. Successful applicants were also given a copy of the Energy Demo "Retrofit Guidelines" (see Appendix A) which summarized the major technical features of various retrofits.

Despite significant modifications to the retrofit proposals, a large number of applications were still unable to meet the Selection Criteria. Of the 154 houses which were audited, 113 met the criteria of the program. However, several of these dropped out of the program for a variety of reasons including an unwillingness to delay construction, frustration with paperwork, death, divorce, job transfers, etc. Only 83 houses were eventually retrofitted as part of the program.

2.3.7 Retrofits

Upon receipt of the contract, the homeowner was free to commence construction of the retrofit. In some cases, the homeowners performed all or most of the construction themselves. In other instances they hired sub-trades to perform specific tasks and completed the balance while in a few cases they turned the project over to a single contractor who coordinated the activities of all sub-trades on the project. The homeowners were encouraged to utilize the assistance of both the Consultants and E & M for information and guidance as questions or problems arose.

2.3.8 Open Houses and Contractors Seminars

While the retrofits were underway, a series of 23 Open Houses were arranged and coordinated by E & M. Local newspaper advertising and direct mailers encouraged the general public to attend and view a energy conservation retrofit in progress. As much as possible, an attempt was made to create a local flavor at the open houses to increase the relevance of energy conservation. In total, 819 people attended, for an average of 36 per Open House.

During the summer of 1983 a one day Contractors Seminar was held in Winnipeg to provide information to the industry on many of the conservation techniques and systems being employed in the Energy Demo retrofits. A second seminar was held in Brandon during that fall. Homeowners were also in attendance at the Brandon Seminar. Speakers were provided by E & M and the Consultants. A third seminar was planned for Thompson but cancelled due to lack of interest.

2.3.9 Site Visits

During the construction phase of each retrofit, up to four site visits were made to each house by the Consultant (the number of visits depended on the complexity of the retrofit). The homeowner was required to notify the Consultant to arrange visits at critical stages in the construction process, for example prior to covering a new air/vapour barrier. The visit

ensured that the terms of the homeowner's contract were being followed and that questions or problems could be reviewed and discussed on site.

On completion of the retrofit, the homeowner notified E & M who requested that the Consultant perform a final site visit. The Consultant checked that the work had been completed in accordance with the contract and performed a post-retrofit airtightness test.

2.3.10 Administration

Administrative duties were the responsibility of E & M. With a project of this size a tremendous volume of correspondence, reports and discussions had to be handled. The administrative duties included:

- o Shepherding each application through the "system".
- o Keeping homeowners current on the status of their applications.
- o Preparing homeowner's contracts.
- o Making progress and final payments to each successful applicant as the retrofit progressed.
- o Coordinating the Consultant's site visits.
- o Coordinating Open Houses and other information transfer activities.

2.3.11 Monitoring

As this report is being written (March, 1985), efforts have been initiated for monitoring of the 83 retrofitted houses to permit comparisons between the predicted and actual changes in energy consumption.

A homeowners survey was also prepared and distributed by E & M to solicit comments on the homeowner's perceptions of changes in the house's performance (in terms of energy use, comfort levels, etc.) as well as their impressions of the Energy Demo program.

HOTCAN simulations were also being re-run on each of the 83 retrofitted houses to simulate their actual pre- and post-retrofit performance. As discussed in Section 5, the initial HOTCAN runs used standardized values for many of the input variables such as house

temperatures, appliance use, etc. because the primary purpose of the simulations was to determine the house's eligibility for the program. The re-run simulations were designed to model the house as actually operated before and after the retrofit. They also permitted any changes to the retrofit to be accounted for which may have occurred after the original simulations had been performed.

Finally, documentation has been prepared to permit analysis of utility records on the houses at some future point. At the time of writing, most of the 83 houses were completing their first heating season in a post retrofit state.

2.3.12 Information Transfer

During the Energy Demo program, a great deal of general and specific knowledge was acquired on residential energy conservation. Much of this information has been incorporated by E & M into the creation and upgrading of technical literature which it distributes to the general public. Further, this knowledge was used in two subsequent residential energy conservation projects - the T.E.A.M. (Town Energy Audit Match) and Home CHEC-UP (Cut Home Energy Costs) program. Both are described in more detail in Section 8.

Specific documentation of the Energy Demo program is contained in this report and in a Summary Report.

SECTION 3

DESCRIPTION OF THE ENERGY DEMO HOUSES AND RETROFITS

3.1 INTRODUCTION

This section of the report briefly reviews the major characteristics of the 154 houses which were audited during the Energy Demo program and provides a more detailed discussion of the 83 retrofits. It also includes a summary description of the types of retrofit measures undertaken in the project. Much of the data which appears has been summarized from the information in Appendices C and D which provide detailed descriptions of each of the 154 audited houses.

3.2 DESCRIPTION OF MANITOBA HOUSING STOCK

Prior to discussing the Energy Demo houses, it is worthwhile to review briefly the characteristics of Manitoba housing stock. Manitoba contains approximately 248,000 single detached houses, representing 5% of the national total (Ref. 1). Residential construction practices within Manitoba have evolved over the years to produce a housing stock which, though similar to other Canadian housing stocks, is unique in certain respects. To provide a framework for reviewing the project houses, the following description of "typical" house construction practices in Manitoba has been prepared:

Foundations

- Predominantly full basements with some partial basements or crawl spaces in some older construction, a few slab-on-grades.
- Stone and mortar or rubble construction in 19th century houses with poured concrete in newer houses.
- Cast-in-place floor systems in both types of foundations.

Exterior Walls	- Almost completely wood frame construction (2 x 4 or 2 x 6), very little structural masonry construction.
	- Balloon framing in older houses and platform framing in new construction.
	- Full or partial wall cavity insulation. Mainly wood shavings in older construction and mineral or glass fibre batts or cellulose fibre in newer houses. Virtually no urea formaldehyde foam insulation.
	- Lath and plaster interior finish in older houses and drywall in new construction.
	- Board sheathing both inside and outside on many older frame houses.
	- Mainly wood or stucco exterior finish in older construction and predominantly stucco in newer houses (although often with a brick, stone or wood finish on walls which face the street).
Windows	- Usually double glazing, (single glazing with a storm window). Triple glazing is common in modern construction.
	- Vertical single-hung sliders with exterior storm windows in older houses with non-operating, casement or awning types in more recent construction.
Doors	- Storm doors usually included.
	- In older construction, one door often opens into an unheated porch.
Roof Systems	- Rafter construction in older houses, trusses in more recent houses.
	- Asphalt shingles in most cases.
Heating Systems	- Mainly forced-air furnaces with some baseboard heating.
Space Heating Fuel	- Natural gas - 62% Electricity - 21% Oil or other liquid fuels - 12% Wood - 5% (Ref. 2)

Domestic Hot Water Heating	- Approximately equal numbers of natural gas and electricity DHW heaters.
Period of Construction	- 1920 or before - 13% 1921 to 1945 - 19% 1946 to 1960 - 29% 1961 to 1975 - 29% 1976 to 1981 - 12% (Ref. 2)

3.3 THE ENERGY DEMO HOUSES

Neither the 154 houses which were audited nor the 83 which were retrofitted necessarily provided a representative cross-section of Manitoba housing stock. Several factors including the basic eligibility requirements of the program biased the sample group of houses away from the provincial norm. For example, the eligibility requirements eliminated newer houses (built after December 31, 1970), more expensive structures (assessed at over $64,000), non-detached residences and those in which the owner was not the principal resident.

On a more subtle level, two of the program's technical criteria (requiring a predicted minimum 40% reduction in total predicted energy consumption and relatively cost-effective retrofits) biased the eligibility toward those houses which could be termed "energy wasters". Those which had been originally built or subsequently retrofitted to even moderate conservation standards commonly had difficulty meeting these criteria or competing against other houses which had low insulation levels, inefficient space heating systems and large amounts of natural air leakage.

3.3.1 Breakdown By Region, House Type and Vintage

A breakdown of the location, type and vintage of the 154 houses audited is given in Figure 3.1. A similar breakdown is provided in Figure 3.2 for the 83 houses that were accepted into the program and retrofitted. The geographic distribution of the 83 funded houses reflects to some extent the desire to allocate demonstration houses throughout the province according to population patterns. However due to a larger-than-anticipated

FIGURE 3.1

HOUSE BREAKDOWN BY REGION, TYPE AND VINTAGE,

AUDITED HOUSES (154)

ALL HOUSES

House Type	1 Storey	1 1/2 Storey	1 3/4 - 2 Storey	2 1/2 Storey	Split Level	All Types
Winnipeg	36	22	20	11	4	93
Other Manitoba	26	13	16	5	1	61
Totals	62	35	36	16	5	154

PRE-1945

House Type	1 Storey	1 1/2 Storey	1 3/4 - 2 Storey	2 1/2 Storey	Split Level	All Types
Winnipeg	9	10	14	11	0	44
Other Manitoba	4	8	16	5	0	33
Totals	13	18	30	16	0	77

1945 - 1970

House Type	1 Storey	1 1/2 Storey	1 3/4 - 2 Storey	2 1/2 Storey	Split Level	All Types
Winnipeg	27	12	6	0	4	49
Other Manitoba	22	5	0	0	1	28
Totals	49	17	6	0	5	77

FIGURE 3.2
HOUSE BREAKDOWN BY REGION, TYPE AND VINTAGE
RETROFITTED HOUSES (83)

ALL HOUSES

House Type	1 Storey	1 1/2 Storey	1 3/4 - 2 Storey	2 1/2 Storey	Split Level	All Types
Winnipeg	23	13	10	8	2	56
Other Manitoba	9	7	6	4	1	27
Totals	32	20	16	12	3	83
Percent of Audited Houses in Category Accepted	52%	57%	44%	75%	60%	54%

PRE-1945

House Type	1 Storey	1 1/2 Storey	1 3/4 - 2 Storey	2 1/2 Storey	Split Level	All Types
Winnipeg	7	6	6	8	0	27
Other Manitoba	4	5	6	4	0	19
Totals	11	11	12	12	0	46
Percent of Audited Houses in Category Accepted	85%	61%	40%	75%	0%	60%

1945 - 1970

House Type	1 Storey	1 1/2 Storey	1 3/4 - 2 Storey	2 1/2 Storey	Split Level	All Types
Winnipeg	16	7	4	0	2	29
Other Manitoba	5	2	0	0	1	8
Totals	21	9	4	0	3	37
Percent of Audited Houses in Category Accepted	43%	53%	67%	0%	60%	48%

percentage of applications from Winnipeg and the greater ability of these houses to meet the program requirements, the percentage of Winnipeg houses retrofitted was higher than planned.

Comparing the audited and retrofitted houses, it is evident that, as expected, older (pre-1945) houses were more successful at meeting the program requirements than newer structures. This reflects the higher conservation standards to which newer houses have been constructed.

3.4 DESCRIPTION OF RETROFITS

For the purposes of discussion, each "retrofit" was considered to consist of a series of individual "measures" combined to meet the program criteria. Upgrading attic insulation, replacing windows, insulating a basement, etc. were all regarded as measures which could be combined to form a retrofit package.

As with the project houses in general, the retrofits performed were not necessarily indicative of what is feasible or practical for the province's entire housing stock. Nor do the retrofits represent the public's perception of retrofit measure priorities, since the selection of the measures was strongly influenced by the energy audit's recommendations. These recommendations tended to re-direct the homeowner towards more cost-effective conservation measures.

Figure 3.3 contains a summary of the retrofit measures actually carried out on the 83 houses. The most commonly applied conservation measures were the application of interior basement insulation (usually with glass fibre batts), upgrading of attic insulation, replacement of furnaces and boilers with more efficient units and air leakage sealing.

3.5 ENERGY COSTS

A summary of typical energy costs in effect during mid-1983 is given in Figure 3.4. These are worth reviewing since the cost of energy and the relative cost differences between various energy forms played a strong role in the selection of the retrofit measures.

FIGURE 3.3
SUMMARY OF RETROFIT MEASURES

	All Projects	Winnipeg	Other Manitoba	pre-1945	1945-70
Total Number:	83	56	27	46	37
Percentage of Total in Category:					
Air leakage sealing major ($200+)	44.6%	35.7%	63.0%	56.5%	29.7%
minor	27.7	28.6	25.9	21.7	35.1
Windows replace one or more	25.3	23.2	29.6	32.6	16.2
upgrade/add storms (eg. 3rd pane)	16.9	14.3	22.2	13.0	21.6
Doors: replace wood by wood	4.8	5.4	3.7	8.7	0.0
replace wood by metal	10.8	5.4	22.2	15.2	5.4
upgrade/add storm doors	0.0	0.0	0.0	0.0	0.0
Walls: insul./reinsul.cavities	16.9	14.3	22.2	28.3	2.7
Interior upgrade: rigid	3.6	0.0	11.1	6.5	0.0
batts (glass fibre)	4.8	7.1	0.0	6.5	2.7
Exterior upgrade:insul.sheath.	9.6	8.9	11.1	2.2	18.9
batts (glass fibre)	6.0	3.6	11.1	8.7	2.7
Double wall	7.2	5.4	11.1	6.5	8.1
Floors, exposed	6.0	7.1	3.7	10.9	0.0
Basement: interior: rigid	0.0	0.0	0.0	0.0	0.0
interior: batts	74.7	83.9	55.6	71.7	78.4
exterior: rigid	18.1	12.5	29.6	13.0	24.3
exterior: batts	4.8	3.6	7.4	4.3	5.4
Ceilings and Attics	66.3	69.6	59.3	65.2	67.6
Mech/elec: replace heating plant	61.4	55.4	74.1	58.7	64.9
heat recovery ventilator	2.4	1.8	3.7	2.2	2.7
minor elec./mech.	39.8	42.9	33.3	39.1	40.5

FIGURE 3.4

TYPICAL ENERGY COSTS
(EFFECTIVE JUNE , 1983)

ENERGY SOURCE	COST IN CONVENTIONAL UNITS	COST IN $/GIGAJOULE
Electricity	2.77¢/kwh	$7.69/GJ
Natural Gas Winnipeg Brandon	 47.83¢/ccf 42.55¢/ccf	 $4.53/GJ $4.03/GJ
Propane	25 to 26¢/litre	$9.19 to $9.56/GJ
Oil	30.1 to 33.7¢/litre	$7.78 to $8.71/GJ

Notes:

1. kwh = kilowatt-hour
2. ccf = one hundred cubic feet
3. All costs are at run-off rates and do not include applicable municipal and provincial taxes.
4. All costs are based on a 100% efficiency of conversion to heat.

SECTION 4

TECHNICAL AND ECONOMIC ANALYSIS OF THE RETROFIT MEASURES

4.1 INTRODUCTION

To meet the technical criteria of the Energy Demo program a number of individual retrofit measures were required for each house. These took several forms and were employed in a variety of combinations. Rather than attempting to review each of the project houses on an individual basis, the experiences and information gained during the project have been collected and are presented for:

- o Foundations
- o Exterior Walls
- o Windows
- o Doors
- o Attics & Ceilings
- o Air Leakage Sealing
- o Heating & Ventilation Systems

Each of these measures is reviewed separately according to the following four part format:

Existing Conditions - Reviews the condition of the project houses in the pre-retrofit state with a particular emphasis on the existing conservation levels and component state-of-repair.

Retrofit - Reviews specific details of the retrofits with some discussion of the applicability of the various types to different situations.

Relative Cost Effectiveness - Summarizes, for comparison purposes, the relative cost effectiveness of the measure.

Summary - Provides a final summary of the major conclusions.

Energy Demo was conceived, planned and delivered as a demonstration program and not as a rigorously controlled experiment to quantify

accurately the energy savings, payback periods, etc. The numerical results which are reported should not be regarded as definitive statements but rather as relative indicators. Despite the limitations of the data base, the experience of the Energy Demo program did provide a valuable insight into the costs and benefits of residential energy conservation retrofits.

The relative cost effectiveness of each retrofit measure is described using its estimated "Payback Proxy". The Payback Proxy was calculated by dividing the cost of the measure by the predicted reductions in the annual energy bill which it would produce as calculated using HOTCAN and mid-1983 energy prices. For the reasons discussed below, the Payback Proxy should not be regarded as the payback period but simply as an indicator of the relative cost effectiveness of the measure.

The price quotations were taken from data on the 83 retrofitted houses and did not include information from the audited, but not retrofitted, houses. This was because many of the initial quotations supplied in the original homeowner applications were considered to be of questionable accuracy. Further all homeowners who were accepted into the program were required to re-submit quotations based on the modifications recommended by the energy audit. As a result, only data for the more cost-effective retrofit measures is included in the calculation of Payback Proxies. For example, cases were encountered of proposed window replacements with Payback Proxies of over 100. Such items were usually removed from the retrofit proposal and thus did not influence the final figures for window replacements.

Another factor to consider is the accuracy of the HOTCAN predicted savings. Although a formal comparison between predicted pre-retrofit loads and actual utility records was not performed, casual comparisons suggested that the HOTCAN results tended to over predict space heating loads and hence the attainable savings possible with retrofitting. Possible reasons for this are discussed in Section 5 but, in brief, the consequence is that the predicted savings and hence their Payback Proxies may be somewhat optimistic. Further, no monitoring results are yet available to verify the accuracy of the predicted savings. In fact, the writer's belief is that

actual energy savings will be less than predicted since homeowners will tend to operate their retrofitted houses at higher temperatures than they did originally. As a result, the accuracy of the simulations, which all assume equal and standardized before and after operating conditions, will be somewhat eroded. Since most of the retrofitted houses were completing their first winter of operation at the time of writing, the discussions which follow concentrate more on the design and construction of the retrofits and less on their performance.

Finally, a true "economic analysis" would require consideration of such factors as higher resale value of the house, increased property taxes, the time value of money, energy price increases, long-term effects of the retrofit, repair implications, increased comfort levels, etc. Even with consideration of these factors the determination of which measures were "economic" would be subject to interpretation. Definition of "economic" is a subjective evaluation which, when applied to private homeowners, can take as many interpretations as there are homeowners. Any attempt to define "economic" would thus be misleading. Conversely, a set of assumptions and criteria could be established to aid in identification of "economic" measures (such as assumptions on energy price increases, interest rates, etc. and criteria defining acceptable present worth factors). However such an analysis would be equally subjective and perhaps misleading since it could suggest a knowledge and confidence in the analysis which is unjustified.

Thus, the reader is cautioned not to treat the Payback Proxies as actual payload periods but simply as indicators of the relative cost effectiveness of the various conservation measures.

The reader will also notice that a range of typical Payback Proxies is provided for each measure. These are meant to represent the range of values most frequently encountered and which were felt to describe the findings of the program best. They usually do not include the most extreme values.

4.2 APPLICABILITY OF RESULTS

While each of the retrofit measures can be considered separately, it is important to recognize that every house in the project was treated as a unique case. Differences in size, construction styles, insulation levels, workmanship, age, occupancy characteristics, etc., make it very difficult to generalize about the "average" house, basement, heating system or other component.

Discussions of the retrofit measures have to be carefully considered before judging their applicability to other cases. This is particularly true for non-Manitoba houses or those classes of houses not represented in the Energy Demo program.

4.3 FOUNDATIONS

4.3.1 Existing Conditions

A breakdown of the types of foundation construction encountered in the 154 audited and the 83 retrofitted houses is shown in Figure 4.1. Full concrete basements with cast-in-place floor systems were by far the most common type of foundation, especially among post-1945 houses and those located in Winnipeg. Full masonry basements constructed of stone and mortar, rubble, brick or hollow concrete block with the floor joists supported by a sill plate were common among pre-1945 houses. Shallow depth foundations or those with dug-out (or "hurricane") cellars were usually found only in pre-1945 houses located outside of Winnipeg.

There was seldom evidence that the foundations were structurally inadequate although minor cracking was very common. A majority of houses, including those in Winnipeg, were built on heave-susceptible soils and displayed evidence of differential settlement caused by fluctuating soil moisture levels and other factors. Frost action may have also been responsible for some of the damage. Water leakage through visible cracks was often reported by the homeowners, suggesting that the cracks extended through the entire thickness of the wall. Efflorescence on the interio f foundation walls was encountered on a few occasions, in one instance having built up to a thickness of approximately 25 mm to 40 mm over an area of

FIGURE 4.1

FOUNDATION TYPES

	Winnipeg			Other Manitoba			Energy Demo Totals
	pre-1945	1945-70	Total	pre-1945	1945-70	Total	
Number of Audited Houses:	44	49	93	33	28	61	154
Percentage of Houses in Category[2]							
Concrete, full basement[3]	54.5%	98.0%	77.4%	48.5%	64.3%	55.7%	68.8%
Masonry, full basement[4]	40.9	--	19.4	24.2	25.0	24.6	21.4
Shallow footings, dugout bas't.[5]	2.3	--	1.1	24.2	3.6	14.8	6.5
Other[6]	2.3	2.0	2.2	3.0	7.1	4.9	3.2
Number of Retrofitted Houses:	27	29	56	19	8	27	83
Percentage of Houses in Category							
Concrete, full basement[3]	51.9%	96.6%	75.0%	52.6%	50.0%	51.9%	67.5%
Masonry, full basement[4]	40.7	--	19.6	31.6	50.0	37.0	25.3
Shallow footings, dugout bas't.[5]	3.7	--	1.8	10.5	--	7.4	3.6
Other[6]	3.7	3.4	3.6	5.3	--	3.7	3.6

NOTES:

1. Due to rounding, columns may not sum to 100.0%.
2. For houses of mixed foundation type, the main/original/dominant one is reported. For example, some houses with full basements had attached porches (over crawl space) which have been converted to a living space; these are reported as full basements.
3. Reinforced, cast-in-place walls with concrete floor slab.
4. Stone and mortar, rubble, brick, hollow block.
5. Usually rubble, sometimes cast-in-place concrete with or without shallow footing.
6. Pressure-treated wood, concrete slab-on-grade, concrete pads and footings at grade with hollow blocks or posts.

several square meters.

Many foundations were completely bare or minimally insulated. In several instances, the basement area had been finished with panelling or boards, generally laid on strapping against the wall with little or no insulation. Insulation on or under the basement or crawl space floor was seldom encountered.

Due to the low insulation levels, the homeowners usually reported basement areas to be very uncomfortable in the winter months. The heat distribution system was usually not balanced to supply adequate heat to the basement.

4.3.2 Foundation Retrofits

Foundation retrofits were the single most common measure among the 83 retrofitted houses. In 62 of these retrofits, glass fibre batt insulation was applied to the inside of the foundation walls. Exterior insulation (usually rigid foam) was applied to another 19 of the 83 retrofitted houses. The most common insulation strategies were:-

- o RSI 1.41 batts in a 2 x 3 stud frame with RSI 2.11 batts laid horizontally between the frame wall and the foundation wall.
- o RSI 2.11 batts in a 2 x 4 stud frame with RSI 1.41 batts laid horizontally between the frame wall and the foundation wall.
- o RSI 3.52 batts in a 2 x 4 stud frame standing off from the basement wall.
- o RSI 1.76 rigid insulation applied to the exterior of foundation walls (typically in the case of shallow foundations).

The first two strategies were preferred for interior retrofits because the application of batts at right angles would reduce the formation of convection cells, such as could occur with the third strategy along the studs.

Insulation levels in full basements were generally carried full thickness down to the floor except with some shallow foundations where they

were reduced near the floor to prevent frost penetration to the footing level or with stone and rubble foundations because of the mortar's susceptiblity to freeze/thaw damage. No basement floor insulation retrofits were performed due to their very poor relative cost effectiveness.

When moisture seepage through the foundation wall was identified or suspected, a damproof layer, usually 6 mil polyethylene sheet was applied against the inside face of the wall from approximately 0.3 m above grade to the bottom of the wall. Large cracks in the foundation were also repaired (usually from the inside) prior to installation of the new damproof layer. In the majority of cases, it was recommended that rain spouts be directed away from the foundation and that (if possible) the ground be re-graded to direct drainage away from the foundation.

To minimize potential problems with seasonal movement of the floor slab when a new insulated interior basement frame wall was installed, a gap of approximately 15 mm to 30 mm was recommended underneath the bottom plate of the new wall or between the top plate and the underside of the floor joists.

Plumbing and electrical lines often had to be moved or relocated away from the wall if interior insulation was used. In a few cases, hot water tanks also had to be relocated or the wall behind them left uninsulated.

Exterior foundation insulation was generally applied to shallow foundations to reduce heat loss and minimize frost penetration. Extruded polystyrene and, to a lesser extent, expanded polystyrene were the most common materials employed. In several of these cases, the insulation was extended horizontally below grade to provide protection against frost penetration. In at least one case, exterior insulation was recommended for a house with a full depth foundation because the basement contained such large quantities of stored wood, metal and miscellaneous machinery that moving it away from the walls to apply interior insulation would have taken several days. Exterior insulation was also recommended in a few cases where the basement had been previously finished but uninsulated. Most of the foundation retrofits were completed without significant problems.

However, the presence of new insulation, particularly on the interior may make it more difficult to identify and repair foundation cracks in the future. Other, specific problems which occurred included:

- o Insulation of the header area in partial beam fill foundations produced cold floors above the basement along the house perimeter. One innovative solution used pieces of extruded polystyrene angled in between each floor joist to permit a degree of air circulation. This kept the floor warm while still allowing an increase in the header R-value.

- o Poor sealing of the air/vapour barrier, particularly near the floor joists and the floor beam penetrations into the foundation wall. Polyethylene was often loosely stapled in place with numerous air gaps which would permit air leakage and vapour diffusion. A particular problem area was sealing of headers on the sides of the house which ran parallel to the floor joists. These end joist spaces often contained heating ducts, plumbing and electrical lines which made working in these areas very difficult.

- o In some of the pre-retrofit houses, foam insulation had been applied to the interior of foundation walls and left uncovered, creating a major fire hazard.

- o "Bagging" of the bottom plate of new interior frame walls. In several cases the polyethylene damproof course was carried under the bottom plate and up the warm side of the wall to serve as the air/vapour barrier. This technique was not recommended because any moisture which penetrated the batt insulation would be unable to drain out of the wall. When this practice was encountered, the Consultants recommended the polyethylene be slit along the bottom to permit drainage.

- o In a few cases, contractors wanted to apply full-depth interior insulation to shallow foundations which were located in frost-susceptible soils.

- o Proper application of flashing over the top of exterior insulation required cutting into the main wall exterior finish.

- o In one case, the contractor initially installed interior glass fibre insulation with a 25 mm gap between the insulation and the basement wall to "prevent moisture damage to the insulation". This would have negated much of the benefits of the extra insulation by permitting convection currents to bypass the insulation.

- o Vinyl siding was applied over exterior foam insulation and extended below grade without adequate structural support which resulted in loosening of the siding due to soil movement.

- o Absence of an expansion gap under the bottom plate of the new frame wall or between the top plate and the underside of the floor joists to accommodate seasonal movement of the floor slab.

- o High moisture levels in some crawl spaces and dugout cellars due to the absence of a moisture barrier on earthen floors or the presence of an uncovered cistern. In some cases, evidence of wood rot on the floor joists was found.

- o Some problems due to improper application of parging to exterior rigid insulation.

4.3.3 Relative Cost Effectiveness

Interior foundation retrofits were often found to be the most cost-effective retrofit measures. Payback Proxies for interior retrofits with batt insulation generally ranged from 4 to 11 with the lower values occurring for oil-heated houses and larger values for houses with case-specific problems such as existing panelling which had to be removed before insulation could be applied. In most cases the retrofit also increased the usability of the space by signficantly improving its appearance and comfort level.

Payback Proxies for exterior foundation retrofits ranged from 3 to 18 although only a limited number of such retrofits were performed. Aside from raising comfort levels, this retrofit technique was also expected to increase the stability of the foundation.

The energy savings attained from foundation retrofits may be offset to a degree by the higher temperatures at which the basement is operated after the retrofit. In some cases, the increase in basement temperatures is expected to be quite pronounced so that the anticipated savings could be significantly less than estimated.

4.3.4 Summary

- o Retrofitting of foundations which had previously been uninsulated was predicted to be a relatively cost-effective means of saving energy. However the savings could be offset in some cases by the higher temperatures at which the basements may be maintained after the retrofit.

- o Significant side benefits from foundation retrofits included increased comfort levels, improved appearance of basement space and increased foundation stability in some cases.

- o The most significant potential problems with foundation retrofits may be the creation of cold floors along the main floor perimeter caused by insulation of the header areas and the increased difficulty in detecting and repairing new foundation cracks because of the presence of the insulation.

4.4 EXTERIOR WALLS

4.4.1 Existing Conditions

A breakdown of exterior wall types in the 154 audited and 83 retrofitted houses is shown in Figure 4.2. Wood frame construction was by far the most common with only a small amount of masonry construction evident, usually in pre-1945 houses. Newer wood frame construction was generally platform framed while balloon framing was more common in older houses. Lath and plaster was the most common type of interior surface finish in older construction and drywall the most common in newer houses.

Figure 4.3 summarizes the types of exterior finish found on the project houses. Stucco was the most common finish, particularly on post-1945 houses and those located in Winnipeg. However, wood siding makes up approximately half of the cases in the pre-1945 group.

In older wood frame construction, wall cavities were sometimes uninsulated or filled with wood shavings. Some houses from this period had been retrofitted with cellulose fibre insulation. Newer houses were typically insulated with glass or mineral fibre batt insulation, typically with RSI 1.23 or RSI 1.41 partial cavity batts or RSI 2.11 full cavity insulation. A few other miscellaneous types of wall "insulation" were also encountered, perhaps the oddest being concrete.

FIGURE 4.2

EXTERIOR WALL TYPES

	Winnipeg			Other Manitoba			Energy Demo Totals
	pre-1945	1945-70	Total	pre-1945	1945-70	Total	
Number of Audited Houses:	44	49	93	33	28	61	154
Percentage of Houses in Category[1]							
Wood frame	88.6%	100.0%	94.6%	81.8%	96.4%	88.5%	92.2%
Masonry[2] (brick, block, tile)	9.1	--	4.3	15.2	--	8.2	5.8
Other[3]	2.3	--	1.1	3.0	3.6	3.3	1.9
Number of Retrofitted Houses:	27	29	56	19	8	27	83
Percentage of Houses in Category[1]							
Wood frame	85.2%	100.0%	92.9%	68.4%	100.0%	77.7%	88.0%
Masonry[2] (brick, block, tile)	11.1	--	5.4	26.3	--	18.5	9.6
Other[3]	3.7	--	1.8	5.3	--	3.7	2.4

NOTES:

1. Due to rounding, columns may not sum to 100.0%.
2. Masonry includes double brick and hollow concrete tile.
3. Other includes examples of solid wood construction and brick/wood frame (interior/exterior) combination.

FIGURE 4.3

EXTERIOR WALL FINISH TYPES

	Winnipeg			Other Manitoba			Energy Demo Totals
	pre-1945	1945-70	Total	pre-1945	1945-70	Total	
Number of Audited Houses:	44	49	93	33	28	61	154
Percentage of Houses in Category[1,2,3]							
Stucco	36.4%	95.9%	67.7%	27.3%	67.9%	45.9%	59.1%
Masonry	2.3	--	1.1	9.1	--	4.9	2.6
Wood	54.5	2.0	26.9	54.5	25.0	41.0	32.5
Vinyl	--	--	--	3.0	--	1.6	0.6
Metal	--	2.0	1.1	3.0	7.1	4.9	2.6
Other[4]	6.8	--	3.2	3.0	--	1.6	2.6
Number of Retrofitted Houses:	27	29	56	19	8	27	83
Percentage of Houses in Category[1,2,3]							
Stucco	37.0%	93.1%	66.1%	31.6%	75.0%	44.4%	59.0%
Masonry	--	--	--	15.8	--	11.1	3.6
Wood	59.3	3.4	30.4	47.4	12.5	37.0	32.5
Vinyl	--	--	--	5.3	--	3.7	1.2
Metal	--	3.4	1.8	--	12.5	3.7	2.4
Other[4]	3.7	--	1.8	--	--	--	1.2

NOTES:

1. Due to rounding, columns may not sum to 100.0%.
2. For cases of mixed finishes, predominant type is reported. For example, it was common to have three sides finished with stucco and the fourth to be finished with one or more other materials, e.g. brick, wood siding, etc.
3. In several cases a new layer of siding covers an older one of similar or different type.
4. Asphalt-coated fibrous siding, etc.

Vapour barriers were seldom encountered in pre-1945 construction. Houses constructed during the 1945 to 1960 period typically used waxed paper as the vapour barrier while post-1960 houses employed polyethylene sheet.

Wall assemblies were usually in good condition. Evidence of moisture damage was found in a small number of houses. The worst cases were those in which the moisture penetrated the wall assembly from the exterior. Mould or mildew was found on interior wall surfaces in some houses with low air change rates. Major structural defects were seldom encountered.

4.4.2 Exterior Wall Retrofits

Exterior wall retrofits were performed on 40 of the 83 funded houses. Generally, the retrofit was intended to increase the insulation level and reduce air leakage. However exterior retrofits often dramatically improved the appearance of the house while interior retrofits enhanced the appearance of the interior living space. Six types of exterior wall retrofits were constructed under Energy Demo:

- Insulation of empty or partially empty wall cavities. In 14 of the retrofitted houses, wall cavity insulation was added. In most cases, cellulose fibre or glass fibre was blown into empty cavities; in a few situations, the cavities were simply topped-up where settlement of the existing insulation (usually wood shavings) had taken place. In a small number of cases, interior or exterior wall surface finishes were removed and the existing insulation, which had been damaged or experienced settlement, replaced.

- Interior rigid insulation. In a few cases, rigid polystyrene or polyurethane insulation was applied over the interior wall surface.

- Interior glass fibre batts. In a small number of cases, glass fibre batts were applied to the interior of wall surfaces between horizontal or vertical 2 x 2 strapping.

- Exterior rigid insulation. In 8 of the houses, some form of rigid or semi-rigid insulation, was applied to the exterior, usually polystyrene or semi-rigid glass fibre.

- o Exterior glass fibre batt insulation. In a small number of cases, glass fibre batts were applied in a new exterior wood frame wall, typically constructed using 2 x 4 framing (the so-called "single wall retrofit"). The new wall was constructed to rest flush against the exterior surface of the existing wall.

- o Double wall retrofits. Double wall retrofits were constructed on 6 of the 83 retrofitted houses. Although slight variations occurred, the most common system was a 2 x 4 stud wall standing off the existing wall a distance of 90 mm to 140 mm. RSI 2.11 to RSI 3.52 glass fibre batts were laid horizontally in the space between the new and existing walls and RSI 2.11 batts were placed in the cavities of the new wall. In most cases, a new 6 mil sealed polyethylene air/vapour barrier was installed over the existing wall surface prior to construction of the new wall.

Interior wall retrofits were often selected because they were not weather-dependent and could be constructed at any time of year. Also they did not require scaffolding to work on the upper levels of the house and were not affected by limited lot setbacks or overhangs. Structural problems with the support of the new wall were seldom a problem. However because of the extensive disruption to the interior, they were usually performed only when major interior renovations were planned. They also reduced the living area of the house.

Exterior wall retrofits were usually preferred because no disruption to the living space occurred and the retrofit did not reduce the usable living area of the house. If a new air/vapour barrier was installed over the existing wall, better air sealing could also be obtained. Because of the visibility of the retrofit, the possibility of increased property taxes perhaps may be greater relative to other types of retrofits.

For both approaches however, consideration had to be given to the possible need to replace doors or windows in the future.

The majority of exterior wall retrofits were completed without major problems, although considerable planning was usually required to design the details of the retrofit. Many contractors were unfamiliar with the details of major wall retrofits. The most frequent problems with exterior

wall retrofits included:

- o The possible need to relocate natural gas and electrical lines.
- o Inadequate overhangs to accommodate the additional wall thickness, especially at gable ends.
- o Very limited setbacks from property lines which restricted the allowable increase in wall thickness.
- o Detailing of door and window penetrations.
- o Provision of adequate structural support for the new wall.
- o Poor examinations of the existing wall to estimate the insulation level and hence determine the most appropriate retrofit measures.
- o Poor patching of interior or exterior holes through which insulation was blown into the wall cavities.
- o Examples of poor stucco work.
- o Increases in air leakage rate after a single wall retrofit because the original stucco, which formed an excellent air barrier, had been removed and replaced by a more porous exterior wall finish.
- o Construction site damage to some of the more fragile rigid insulations.
- o Possible fire hazards from the application of exterior insulation around a protruding fireplace and/or chimney.

4.4.3 Relative Cost Effectiveness

The relative cost effectiveness of insulating empty wall cavities was generally predicted to be good. Payback Proxies values ranged from approximately 2 to 8.

In contrast, the Payback Proxies of other types of exterior wall retrofits were considerably greater, typically ranging from 12 to 43. Interior and exterior wall retrofits dramatically improved the appearance of the house. As well as the obvious aesthetic gains, a proportion of the retrofit cost may prove to be recoverable in the higher re-sale value of the house, although property taxes may also increase.

4.4.4 Summary

- o The application of insulation to empty wall cavities was predicted to be relatively cost effective.
- o Retrofitting of exterior walls using other techniques such as the application of rigid insulation, strapping, single or double walls was predicted to be significantly less cost effective. These types of retrofits were found to be most economical when the house was due for re-siding or the interior finish was in need of replacement.
- o Exterior wall retrofits required careful planning to consider the possible relocation of utility lines, available overhangs, lot setbacks and structural detailing.
- o Exterior wall systems required careful examination to determine existing insulation levels before work could proceed on the retrofit.
- o Interior and exterior wall retrofits usually produced significant improvements in the appearance and possible resale value of the house.

4.5 WINDOWS

4.5.1 Existing Conditions

Virtually all major types of windows were encountered during the project, the most common types being wood single-hung units with a wood or aluminum exterior storm, aluminum horizontal sliders, non-operating sealed units, and sashless horizontal sliders. Small numbers of awning and casement windows were also encountered.

Double-glazed windows were the most common but small numbers of single-glazed (largely in rural areas) and triple-glazed units were also found. A few windows were fitted with interior or exterior sheet polyethylene storms.

The physical condition of windows was generally acceptable except in some of the older houses. Decades of accumulated wear and/or moisture damage had impaired the ability of some operating units to function.

Condensation was the most commonly reported window problem, particularly with units on the upper levels of houses which were subject to

air exfiltration. This often produced condensation between the inner and outer panes which froze the window in an open or shut position.

The airtightness of windows varied significantly. Although actual measurements were not performed, smoke pencil examinations of all major leakage areas were made during the airtightness test. This qualitative examination showed that the leakage through individual windows varied from virtually zero to very high levels.

4.5.2 Window Retrofits

Window retrofits generally consisted of replacing old double-glazed units in poor condition with newer triple-glazed units. Twenty-one of the retrofitted houses had one or more windows replaced, generally with sealed unit casements or non-operating units.

In 14 of the retrofitted houses, removable interior or exterior third panes were added to existing double-glazed units. These were constructed from glass or plastic sheet. Interior magnetic or exterior aluminum storms were the most common types. Replaceable plastic film "storms" were usually not included in the retrofits. Triple glazing, as achieved with either a complete new unit or an additional third storm pane, was often required in tighter houses to limit window condensation, especially on north and east faces which had less exposure to the sun.

A few homeowners constructed insulated shutters using rigid foam insulation. One homeowner also modified the geometry of a window awning to increase the solar gains during the heating season.

Few problems have surfaced to date with the window retrofits and most were minor and related to workmanship, although some problems with interstitial condensation on third pane retrofits have been noted.

4.5.3 Relative Cost Effectiveness

Input for the HOTCAN analysis included the estimated effects of changes in air leakage rates and passive solar gains. The analysis of the various retrofits indicated that the cost effectiveness of replacing existing double-glazed windows with new triple-glazed units was extremely

poor. Typical Payback Proxies for replacement of existing double-glazed windows with new triple-glazed units were in the range of 20 to 85. As a result, it was generally recommended that such retrofits be dropped from the retrofit proposals. Those that were funded were often accepted by being lumped into a package with more cost-effective retrofit measures or because the existing windows had physically deteriorated or could not to be properly weatherstripped.

The relative cost effectiveness of third pane storm retrofits was superior to complete replacements. The Payback Proxies for these were typically in the range of 10 to 23.

4.5.4 Summary

- o The relative cost effectiveness of replacing double-glazed windows with new triple-glazed units was extremely poor. Such retrofits were only warranted on aesthetic grounds or if the unit were physically in need of replacement.
- o Third pane storm window retrofits were much more cost effective than complete replacement and were the most economical means of controlling window condensation.
- o Excessive air leakage through existing windows was most economically corrected using proper air leakage sealing techniques.

4.6 DOORS

4.6.1 Existing Conditions

In most cases, there were two doorways per house, each with an interior door and storm door. One of the doorways often opened into an unheated front or rear porch. The most common types of doors were hollow or solid core wood units, often with glazed panels. Storm doors were either of wood or aluminum construction and often contained significant glazed areas.

Most doors, including many designated for replacement in the original homeowner applications were found to be in reasonable condition from a structural and functional perspective. A relatively small number were in such poor physical condition that replacement was the only alternative.

From a heat-loss perspective, most doorways had a low thermal resistance, compared to other components of the building envelope. However since they constituted such a small percentage of the exposed area of the house, the effect upon the structure's total heat loss was minimal.

However, doors were often found to be significant sources of air leakage. Door leakage was most common at the top and bottom and at the four corners and on the hinge side of the unit. Weatherstripping was often non-existent or in very poor condition. In several cases warping of the door prevented weatherstripping from properly mating with the door surface, particularly at the top and bottom.

4.6.2 Door Retrofits

Although door replacements were a popular measure in the initial homeowner applications, a significant number were ultimately dropped from the retrofit. Nine of the 83 funded houses had existing wood doors replaced with metal insulated units. These were most common in older houses. In 4 cases, existing wood units were replaced with new wood doors.

Most door replacements were properly completed although in a few cases air leakage past the weatherstripping was identified during the post-retrofit airtightness test.

In most instances, the existing interior wood door was replaced with a new unit while the exterior storm door was left in place, possibly with some weatherstripping added. When existing units were replaced with metal insulated doors, the existing storm was usually removed because of a concern that solar overheating would develop between a glazed storm and a darkly painted steel door. In extreme cases, such as on south or west sides, this could have led to melting of the plastic trim pieces on the steel door.

Aside from complete replacement, a number of units were weatherstripped to reduce air leakage. Again, some problems were encountered, mainly with the inadequate "reach" of some types of weatherstripping to seal against the door surface. In some rural areas it was also difficult for contractors to buy better quality spring loaded

weatherstripping. To minimize warpage of wood units due to fluctuating moisture levels, a number were painted or sealed to minimize moisture movement.

4.6.3 Relative Cost Effectiveness

The Payback Proxies of replacing existing wood doors with new, insulated metal or wood units were typically in the range of 19 to 48. As a result, many proposed replacements were dropped from the original applications.

In a few instances, door replacements were required because of physical deterioration of the existing unit or for aesthetic or security reasons. In these cases, the marginal costs of upgrading to energy conserving units instead of conventional units were relatively low.

Determination of the energy savings and Payback Proxies were highly sensitive to the values assumed for the thermal resistances of the old and new doors. The values used for the HOTCAN analysis were taken from Ref. 3 and were lower than those published in some product literature.

4.6.4 Summary

- The replacement of existing doors in good or reparable condition with energy-efficient units was predicted to have a very poor relative cost effectiveness.
- The marginal cost effectivenss of replacing existing doors with more energy-efficient designs was usually predicted to be reasonable when the existing doors had to be replaced for other reasons.
- Many doors which homeowners viewed as requiring replacement were successfully and economically retrofitted by proper weatherstripping and sealing.

4.7 ATTICS & CEILINGS

4.7.1 Existing Conditions

Attic and ceiling retrofits performed during Energy Demo can be classified into three groups:

- o Attic retrofits typical of bungalows and 2 storey houses in which the insulation was installed horizontally above the ceiling.
- o Attic/ceiling retrofits typical of 1 1/2, 1 3/4 and 2 1/2 storey houses, in which the insulated shell consisted of pitched, horizontal and vertical sections.
- o Cathedral ceiling retrofits in which the insulated ceiling was pitched at a slight angle. They were occasionally combined with horizontal and vertical sections over portions of the home.

Bungalows and 2 storey house attics were usually insulated with wood shavings, vermiculite, cellulose fibre or with glass or mineral fibre batt insulation. Insulation levels varied, but most pre-retrofit house attics had insulation levels of approximately RSI 2 to RSI 5.

In virtually all cases access was available into the attic, usually through interior hatches, to permit examination of the space and insulation. This seldom revealed major problems. Although watermarks on trusses or the roof sheathing were commonly found, there were few instances in which significant damage such as wood rot was evident. In some of these cases, the problem appeared to have been caused by ice-dams which permitted water penetration through the roof membrane into the attic space.

In several cases it was possible to identify sources of air leakage from the living space into the attic. The most common sources were ceiling-mounted light fixtures and exhaust fans, partition walls, plumbing stacks and attic access hatches. Vapour barriers were usually polyethylene sheet in newer houses and waxed paper in older construction. In very old structures, no vapour barrier was present.

Some attics had been previously re-insulated, often with CHIP assistance. In a few cases, the extra insulation had been added without any attempt to air seal the ceiling, thus creating the potential for long-term moisture problems.

Attic ventilation was usually provided by gable vents mounted near the roof peak. Some newer homes also had soffit vents. A few roof-mounted vents were encountered. In most instances the vents were relatively unobscured by the attic insulation.

Attic/ceiling retrofits typical of 1 1/2, 1 3/4 and 2 1/2 storey structures were most common among the older housing stock. Horizontal sections of the ceiling, behind the kneewalls and under the roof peak, were usually insulated to RSI 1.5 to RSI 3.0 with wood shavings and/or batt insulation. Pitched portions of the ceiling were insulated to lower levels, usually RSI 1.5 to RSI 2.0, because of the limited depth available between the rafters. In several cases, estimates of the types and amount of insulation had to be made because access to these areas was restricted.

Vapour barriers in 1 1/2, 1 3/4 and 2 1/2 storey houses were either non-existent or consisted of poorly installed wax paper or polyethylene. Occasional evidence of moisture damage was found.

In most cases, venting was not provided to the attic spaces or to the rafter cavity on the pitched portions of the ceiling. Where venting was present, small gable-end vents were usually used. Minor amounts of air leakage were usually identified through partition walls and ceiling-mounted electrical fixtures. The dominant source of air and water vapour movement into the attic space behind the kneewalls was through the floor system which provided an easy avenue for air movement from the house interior into the attic spaces.

Cathedral ceilings were encountered in a few houses of which only 3 were retrofitted. Since these houses were relatively new, polyethylene vapour barriers and vented air spaces above the ceiling insulation were found (or assumed in a few cases) to be present. Evidence of moisture damage was noted on the undersides of some ceilings which suggested air exfiltration had occurred, possibly through partition walls and ceiling-mounted electrical fixtures.

4.7.2 Attic & Ceiling Retrofits

In 54 of the 83 project houses, some type of attic or ceiling retrofit was performed. A three-part approach, consisting of air leakage sealing to minimize exfiltration into the attic, upgrading of insulation levels, and (where appropriate) the addition of extra attic ventilation, was used for all retrofits. This approach was designed to save energy and minimize potential maintenance problems by reducing moisture movement into the attic space. Further benefits may have also resulted from the reduction of ceiling heat loss which minimized the potential for ice dam formation.

Bungalow and 2 storey attic retrofits typically involved the addition of RSI 1 to RSI 4 to the existing insulation. Blow-in or batt glass fibre insulation was the most common type used. Cellulose fibre was also used although its application was limited because of concerns about possible moisture damage from roof leaks. Air leakage sealing was frequently carried out from the interior because of the problems with working in the attic. Additional venting was provided, where necessary. Turbine vents were discouraged because of concerns that they would depressurize the attic and thus draw moisture-laden air from the living space into the attic.

Although most work was carried out in a satisfactory manner, some problems did arise. Contractors were often unwilling to bother with air leakage sealing, possibly because of the extra costs or because of a general disbelief in its need. Loosefill insulation was occasionally applied in a very uneven and thus less-effective manner. Insulation was found to be covering soffit vents in some cases. Attic hatches were not mechanically secured in a few cases and became major sources of air leakage.

Retrofitting attics and ceilings in 1 1/2, 1 3/4 and 2 1/2 storey houses proved difficult and expensive. In most cases it was not feasible to add insulation to the pitched portions of the walls so only the horizontal sections and/or kneewalls were insulated. Again, blown or batt glass fibre insulation were the most common types used. In cases where access could be obtained to the space behind the kneewalls, the spaces

between the floor joists were sealed where they penetrated into the attic. Rigid extruded polystyrene or plywood, caulked-in-place with acoustical sealant was the most common technique. In two cases, gable ends of the kneewall attic space had vents added (none were present before) and the estimated natural air infiltration rate rose dramatically. Upgrading insulation levels on the pitched portions of the ceiling was only feasible when major interior renovations were being carried out. In some cases, particularly with 1 1/2 storey houses, rigid extruded polystyrene was installed over the interior of the pitched surfaces and covered with new drywall.

Cathedral ceiling retrofits were only carried out on a few houses. In one case, the existing shingles were due for replacement. The contractor stripped the shingles and plywood roof sheathing, furred out the roof trusses and added extra glass fibre batt insulation with an airspace above the new cavity. In another case, the entire roof was covered with trusses to form an attic above the cathedral ceiling. The attic space was then heavily insulated.

4.7.3 Relative Cost Effectiveness

The relative cost effectiveness of attic and ceiling retrofits varied greatly because of the large differences in the initial insulation levels. Payback Proxies of bungalow and 2 storey retrofits typically ranged from 3 to 10 with a few in the range of 10 to 24. In some cases, retrofits with high Payback Proxies were included because their total cost was small compared to the total project cost or to demonstrate a wide variety of retrofit techniques.

Payback Proxies for retrofitting attics and ceilings in 1 1/2, 1 3/4 and 2 1/2 storey houses were usually higher because of the extra labour required and the restricted space available in which to add insulation. Typical values were in the range of 5 to 12. Results were very dependent on the individual house.

Based on the small number of cathedral ceiling retrofits performed

during Energy Demo, the relative cost effectiveness was poor. Payback Proxies ranged from 8 to 25. This type of work was most logically performed when extensive repairs, such as replacement of the shingles were being made.

4.7.4 Summary

- o Attic retrofits in bungalows and 2 storey houses were relatively cost effective provided the initial insulation level was low.
- o Attic and ceiling retrofits in 1 1/2, 1 3/4 and 2 1/2 houses were less cost effective than bungalow and 2 storey retrofits. They were most economical when major interior renovations were being carried out to the upper levels of the house. Particular emphasis had to be placed on sealing of the floor joist penetrations into the attic spaces behind the kneewalls.
- o Cathedral ceiling retrofits exhibited a relatively poor cost effectiveness and were best performed when other repairs, such as replacement of the shingles, were required.
- o Attic and ceiling retrofits required consideration of three steps to be successful: air leakage sealing, the addition of extra insulation and increased ventilation.

4.8 AIR LEAKAGE SEALING

As previously mentioned, the majority of the 154 audited houses received an airtightness test. (A few were not tested because renovations were in progress or the house was so leaky that an acceptable pressure differential could not be established). A second test was also performed at the completion of construction on each of the 83 retrofitted houses. All tests were performed in accordance with the latest draft of CGSB 149-GP-10M "Standard for Determination of Airtightness of Buildings by the Fan Depressurization Method" (Ref. 4). Using the results of the airtightness test and a derivative of the procedure described in Ref. 5, an estimate was made of the natural air infiltration rate over the heating season. This result, expressed in air changes per hour, was used as input for the HOTCAN simulations.

Once the measured test was completed, the house was de-pressurized and a smoke pencil examination carried out to identify air leakage sources. These were noted on a checklist and a copy was left with the homeowner to serve as a guide for any planned sealing. This process was repeated during the post-retrofit test.

It should be noted that the post-retrofit tests assessed the net change in airtightness due to all the retrofit measures performed on the house, not simply the air leakage sealing. In many cases, these other measures had a significant effect upon the leakage rate.

4.8.1 Existing Conditions

A wide range of airtightness rates was encountered. On one extreme, some houses were found to meet the R-2000 Program airtightness standard. These were typically newer (post-1950) bungalows with a stucco finish (the stucco functioned as an effective air leakage barrier). Further, most of the project houses used cast-in-place floor systems which restricted leakage past the header area. (This is often a major source of leakage in houses which use a sill plate floor system.) The tightest pre-retrofit house was found to have an estimated natural air infiltration rate over the heating season of 0.09 AC/HR as calculated using the technique described in Ref. 5. On the other extreme, the leakiest house was a 2 1/2 storey structure with an estimated natural air infiltration rate of 1.35 AC/HR.

An observation which arose from the completion of the air leakage source checklists was the identification of major air leakage sources for each type of house in the pre-retrofit state. Figures 4.4 through 4.8 summarize this data by house type and leakage source. For example, with reference to Figure 4.4, fireplaces were major sources of leakage in 4 of the 7 bungalows in which they were present, i.e. 57% of the cases. Floor joists in bungalows were identified as major sources in 14 of 42 houses for which data was recorded, i.e. 33% of the cases (a further 16 bungalows were present in the project but their data was missing or the source was judged as not applicable).

FIGURE 4.4 OCCURRENCE OF MAJOR AIR LEAKAGE SOURCES - BUNGALOWS

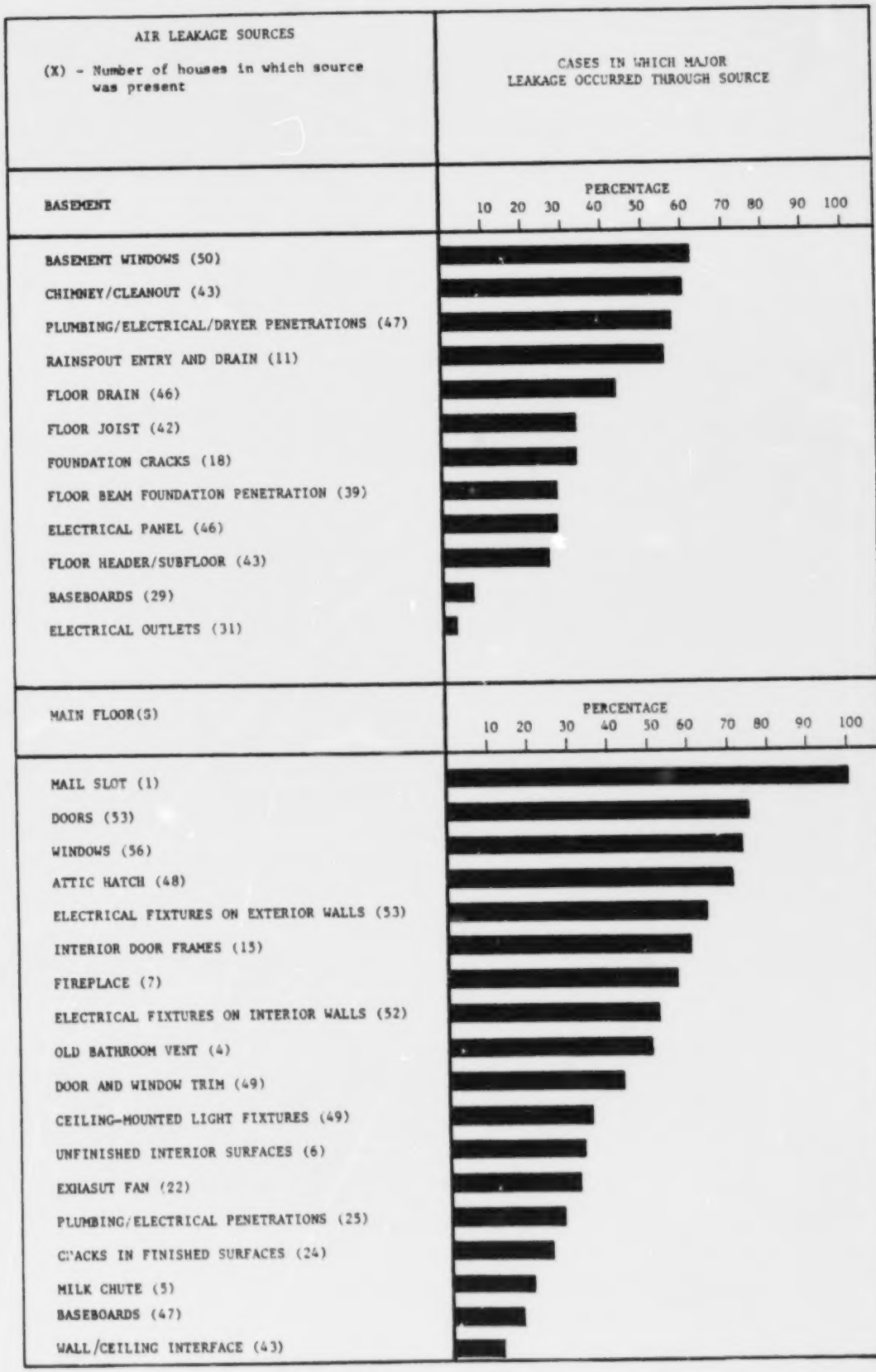


FIGURE 4.5 OCCURRENCE OF MAJOR AIR LEAKAGE SOURCES - 1½ STOREY HOUSES

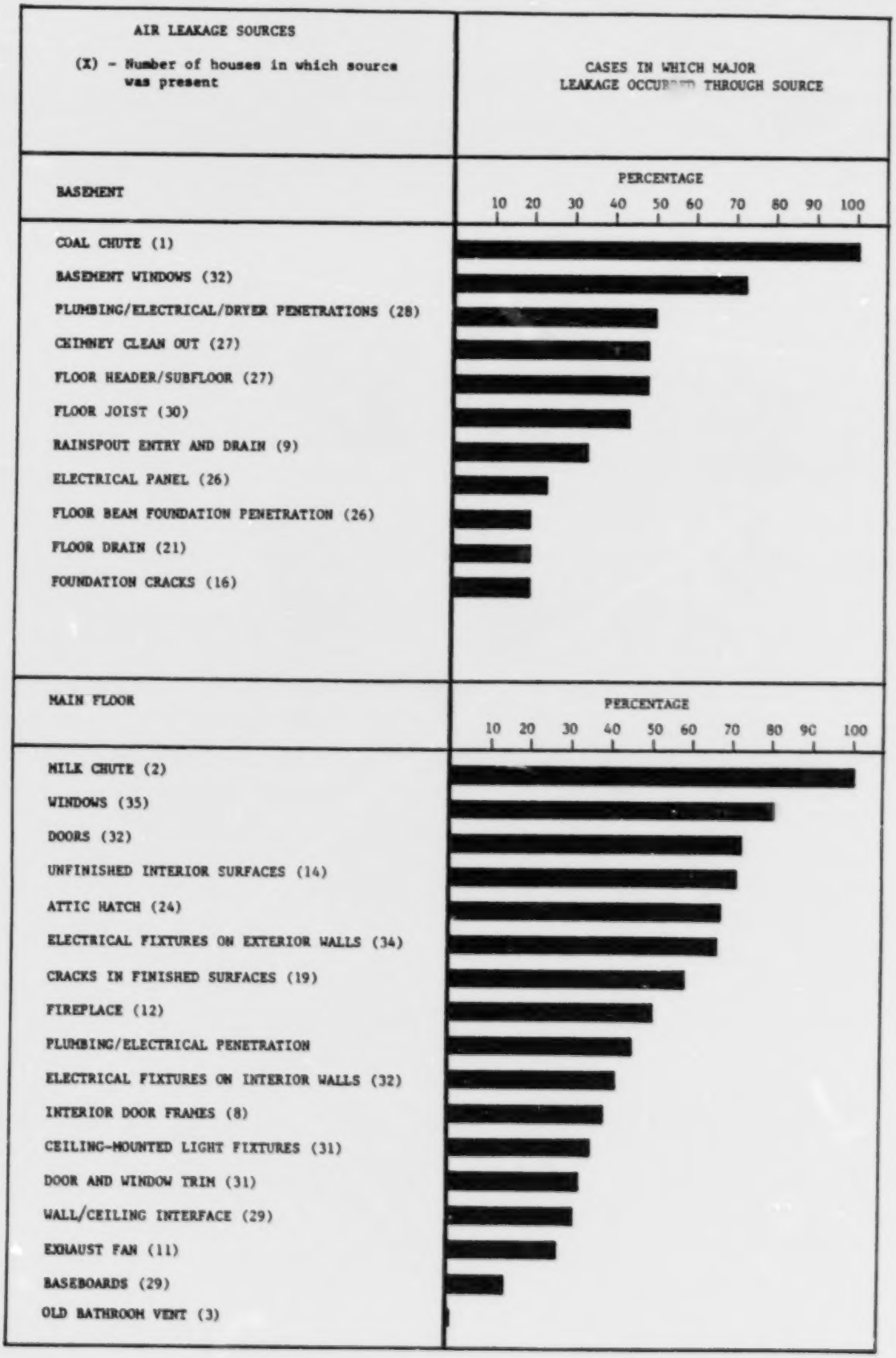


FIGURE 4.6 OCCURRENCE OF MAJOR AIR LEAKAGE SOURCES - 1 3/4, 2 STOREY HOUSES

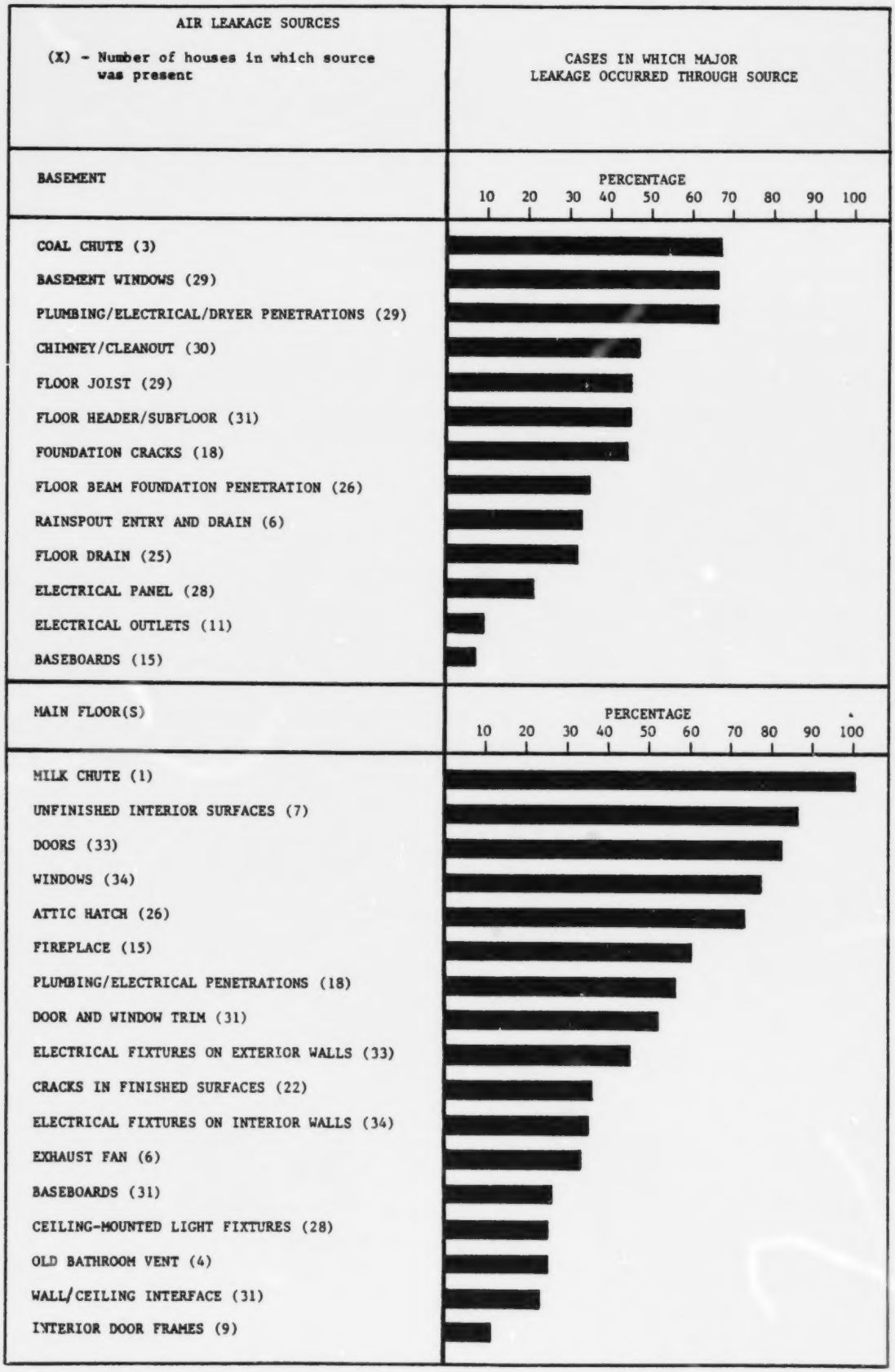


FIGURE 4.7 OCCURRENCE OF MAJOR AIR LEAKAGE SOURCES - 2 1/2 STOREY HOUSES

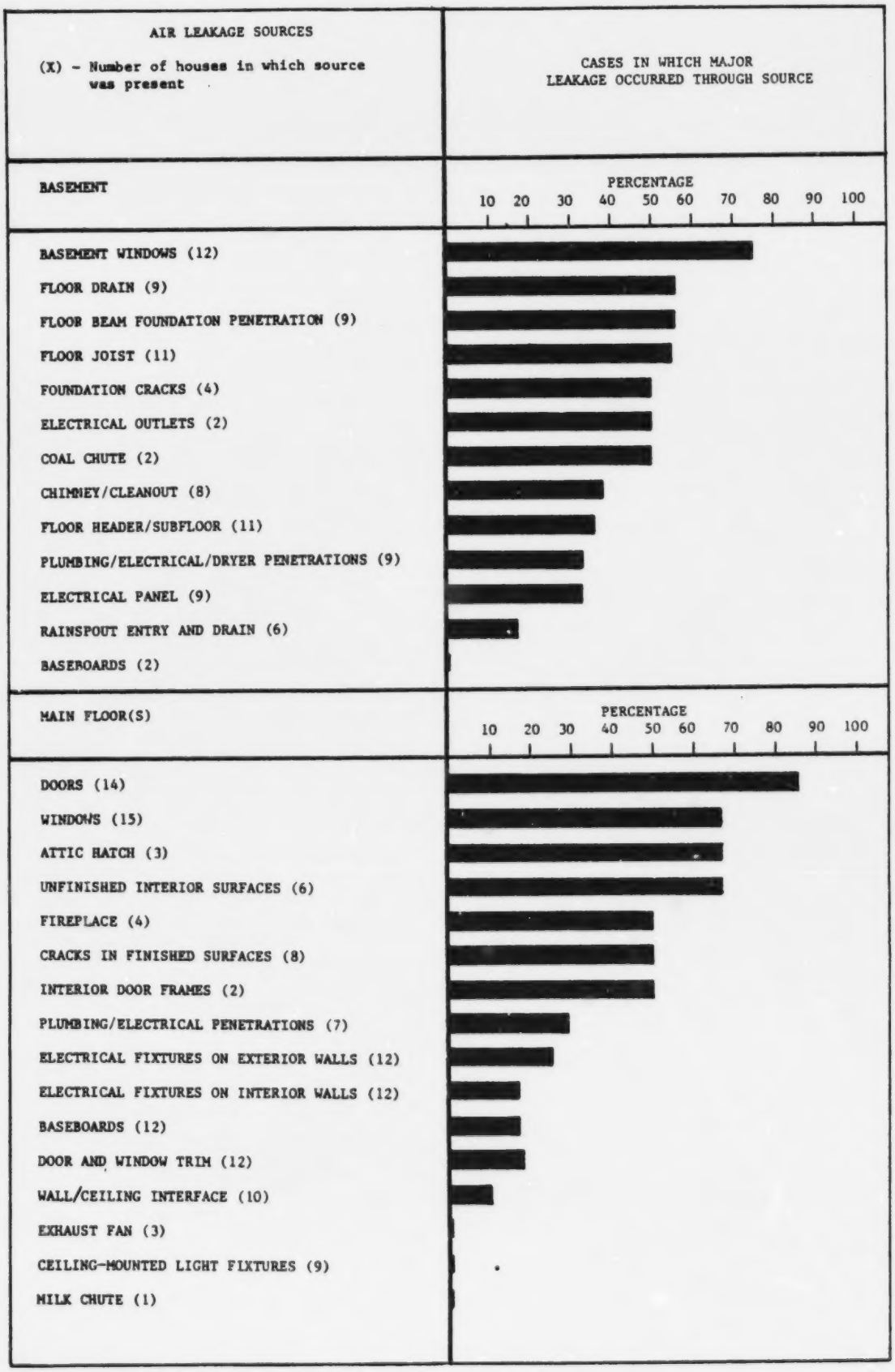
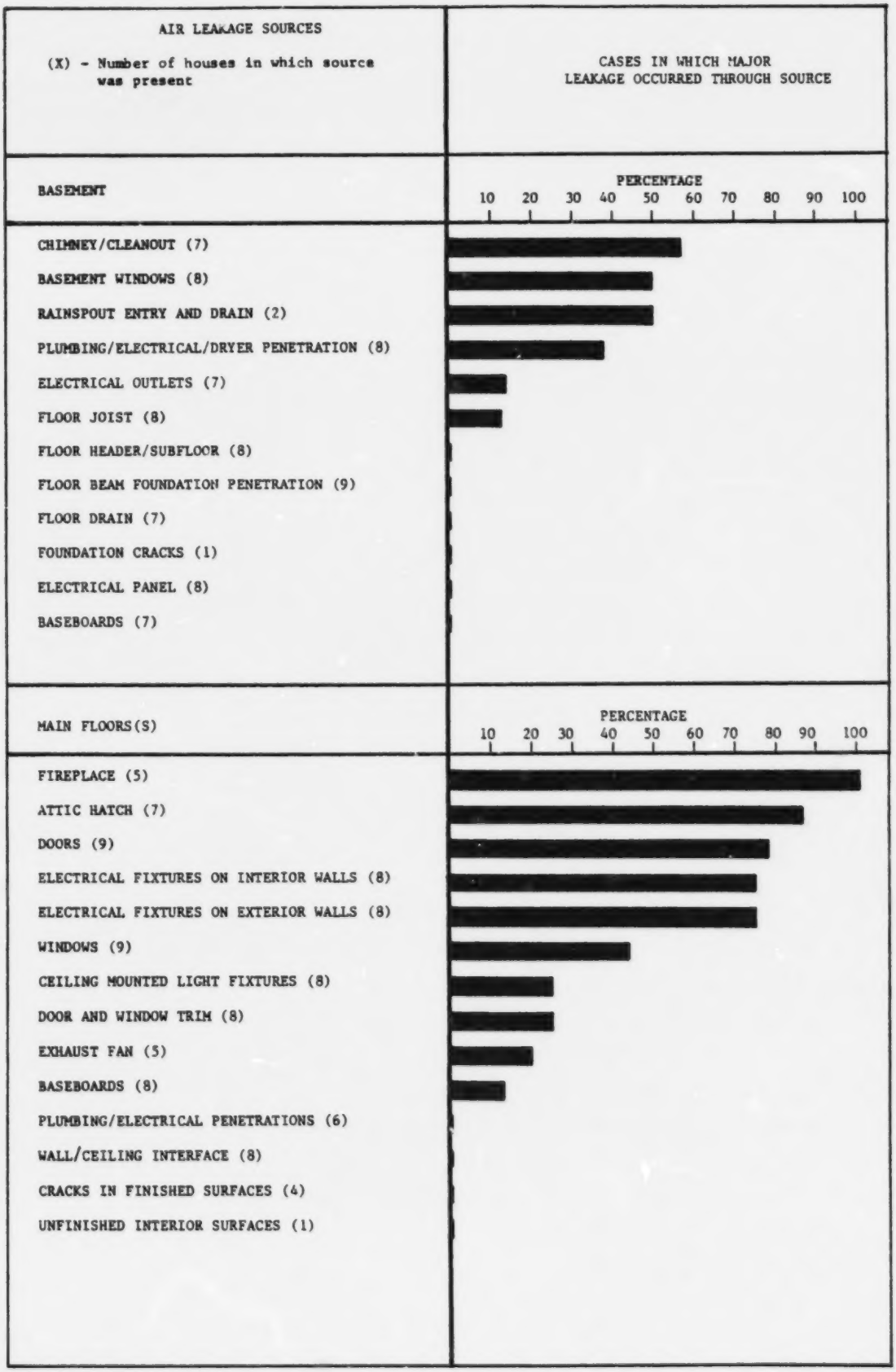


FIGURE 4.8 OCCURRENCE OF MAJOR AIR LEAKAGE SOURCES - SPLIT LEVEL HOUSES



4.8.2 Air Leakage Sealing Retrofits

Air leakage sealing retrofits were classified into two groups - minor retrofits which cost less than $200 (labour and materials) and major retrofits which cost more than $200. Minor retrofits typically consisted of caulking and/or weatherstripping of a few dominant leakage sources while major retrofits represented "whole-house" sealing. Twenty-three of the 83 retrofitted houses received minor sealing work and 37 received major sealing retrofits.

Many of the minor retrofits were performed by homeowners while most of the major jobs were performed by contractors. A large percentage of the major retrofits were performed by one particular contractor who specialized in air leakage sealing and operated his own blower door.

Air leakage sealing was proposed by homeowners with almost the same frequency that it was found necessary by the audit. In several cases however, sealing was either added or deleted from the retrofit, based on the results of the airtightness test. For example, homeowners occasionally proposed sealing even though the house exhibited visible signs of low natural air leakage (such as high relative humidity levels). In other cases, houses in obvious need of major sealing were not recognized as such by the homeowners.

Generally, there was minimal understanding displayed by contractors and homeowners of the need to maintain an adequate air supply for combustion appliances as well as the more general issue of maintaining acceptable indoor air quality. Although these are subjects of intensive research and debate, it must be recognized that contractors and homeowners are the ultimate "practitioners". Any lack of knowledge demonstrated during Energy Demo suggested the need for more training or improved standards.

In general, the post-retrofit examinations revealed that the sealing had been satisfactorly performed. Although individual leakage areas were occasionally missed or poorly sealed, such occurrences were not common. Air leakage sealing was generally performed according to accepted

practices, such as those outlined in Refs. 6 and 7. It should be noted, however, that the technical assistance provided to the homeowner under the Energy Demo program was greater than that to which the general public would normally have access.

Problems were usually isolated in their occurrences. Inconsistent application of caulking with gaps or thin spots, improper choice of caulking, poor installation of weatherstripping, and the odd safety concern (such as one homeowner who planned to spray polyurethane foam into electrical boxes to reduce leakage) were occasionally encountered.

Contractors who specialized in air leakage sealing usually produced the most significant improvements in the leakage rate. Contractors also performed higher quality work than homeowners who performed the job themselves, even though the homeowner was usually present during the Consultant's airtightness test and received a completed copy of the Air Leakage Source Checklist.

4.8.3 Relative Cost Effectiveness

To perform the HOTCAN analysis, the Consultants produced their own estimates of the changes in natural air infiltration which they expected. These estimates were based on the pre-retrofit tightness of the house and hence the opportunity for further tightening, the number of leakage areas identified during the examination and the perceived ability of the contractor or homeowner to seal these sources. Finally, the Consultants relied on their experiences with a similar field study in which the changes in airtightness, due to air leakage sealing, of 82 Manitoba houses were measured (Ref. 8).

As previously described, the pre- and post-retrofit airtightness tests did not indicate the effectiveness of the air leakage sealing alone because of the other retrofit measures carried out simultaneously.

Acknowledging these limitations, the estimated Payback Proxies for air leakage sealing were found to typically be in the order of 1 to 13 with the lowest value describing homeowner-performed sealing.

4.8.4 Summary

- o Based upon subjective estimates of the change in airtightness, the relative cost effectiveness of air leakage sealing retrofits were predicted to be very good especially if the work was performed by the owner.

- o Higher comfort levels due to reduced drafts and better protection of the building shell due to reduced water vapour penetration were also anticipated.

- o Notwithstanding the above, indiscriminate air leakage sealing could lead to serious problems with indoor air quality and the supply of air to combustion appliances. Many houses would not have benefited from air leakage sealing.

- o Better guidelines, standards and testing procedures are needed by contractors, homeowners and energy advisors to safeguard indoor air quality.

- o The blower door was found to be a valuable aid in the identification of air leakage areas.

4.9 HEATING & VENTILATION SYSTEMS

Heating system replacements were a common retrofit measure and included a variety of different strategies. Ventilation system modifications were also common but were generally included for reasons of safety or comfort.

4.9.1 Existing Conditions

The types of primary space heating systems encountered in the audited houses is shown in Figure 4.9. The major space heating fuels in houses in Winnipeg, Brandon and other southern Manitoba cities and towns was natural gas. A small number of these urban homes were heated with electricity or oil. In rural areas, the dominant fuel source was oil with a lesser number of electrically heated houses. Supplemental wood space heating was very common in the country but not in urban areas. In some cases, "supplemental" wood heating was believed to supply a major percentage of the total space heating load. In many instances particularly older,

FIGURE 4.9
SPACE HEATING SYSTEM TYPES

	Winnipeg			Other Manitoba			Energy Demo Totals
	pre-1945	1945-70	Total	pre-1945	1945-70	Total	
Number of Audited Houses:	44	49	93	33	28	61	154
Percentage of Houses in Category[1,2]							
Forced air natural gas	54.5%	91.8%	74.2%	18.2%	21.4%	19.7%	52.6%
Forced air electricity	4.5	2.0	3.2	6.1	28.6	16.4	8.4
Forced air oil	2.3	--	1.1	39.4	25.0	32.8	13.6
Forced air propane	--	--	--	--	21.4	9.8	3.9
Forced air wood/coal	--	2.0	1.1	3.0	--	1.6	1.3
Gravity air natural gas	4.5	--	2.2	--	--	--	1.3
Gravity air electricity	--	--	--	18.2	3.6	11.5	4.5
Gravity air wood/coal	--	--	--	9.1	--	4.9	1.9
Gravity hydronic natural gas	20.5	2.0	10.8	6.1	--	3.3	7.8
Gravity hydronic oil	2.3	--	1.1	--	--	--	0.6
Forced hydronic natural gas	11.4	2.0	6.5	--	--	--	3.9
Number of Retrofitted Houses:	27	29	56	19	8	27	83
Percentage of Houses in Category[1,2]							
Forced air natural gas	51.9%	89.7%	71.4%	26.3%	25.0%	25.9%	56.6%
Forced air electricity	3.7	3.4	3.6	5.3	12.5	7.4	4.8
Forced air oil	3.7	--	1.8	31.6	37.5	33.3	12.0
Forced air propane	--	--	--	--	25.0	7.4	2.4
Forced air wood/coal	--	--	--	5.3	--	3.7	1.2
Gravity air natural gas	7.4	--	3.6	--	--	--	2.4
Gravity air electricity	--	--	--	10.5	--	7.4	2.4
Gravity air wood/coal	--	--	--	10.5	--	7.4	2.4
Gravity hydronic natural gas	25.9	3.4	14.3	10.5	--	7.4	12.0
Gravity hydronic oil	--	--	--	--	--	--	--
Forced hydronic natural gas	7.4	3.4	5.4	--	--	--	3.6

NOTES:

1. Due to rounding, columns may not sum to 100.0%.
2. For hybrid heating systems, mode of greater inferred utilization is reported.

multi-storey houses with poor heat distribution systems, significant amounts of supplemental electric baseboard heating were used to maintain comfortable conditions in some rooms.

Three types of conventional natural gas heating plants were encountered in the pre-retrofit houses: forced or gravity air furnaces, forced air conversions from oil and/or coal and boiler conversions from oil and/or coal. Gas furnaces were most common in newer construction where the existing unit was the original heating plant or in which an original oil furnace had been completely replaced with a new gas unit when gas service became available, beginning in the 1960's. Boiler conversions were most common in older, urban houses. The majority of project houses used forced air heating systems while a minority were heated with hydronic systems. Heating systems were generally oversized, even for houses in the pre-retrofit state.

Natural gas furnaces generally appeared to be in reasonable condition although detailed inspections were not performed. A few obvious problems were uncovered such as corrosion of the vent sections which permitted exhaust gases to leak into the house. Boilers usually appeared to be in very good condition, even after decades of service.

A complaint voiced by many homeowners was that some areas of their houses were quite cold during the winter months. Although this problem was also affected by the insulation and airtightness levels of the houses, it still appeared that the heat distribution systems in many houses were poorly balanced. Most homeowners, and even some contractors, displayed little understanding of the need to balance the systems. This complaint was most common in older houses with hydronic heating systems.

Some of the oil furnaces had not been serviced for many years and in some cases the heat exchanger and even the flue pipe were extensively coated with soot. One flue breaching was almost one-third full.

Another very common problem was that many existing wood heating systems were found to be installed in an unsafe manner. For example, clearances were often inadequate between the appliance or ductwork and

adjacent combustible surfaces such as walls or floor joists. In many cases, the appliance and vent had been installed by the homeowner.

Almost all domestic hot water (DHW) heating systems used gas or electric heating. All oil, electric and some gas heated houses used electric DHW heating. Problems were seldom reported by the homeowner.

Ventilation systems were either non-existent or consisted of kitchen or bathroom exhaust fans and/or fresh air ducts leading into the return air plenums. Fresh air ducts were generally equipped with manual dampers to control humidity although most homeowners were not familiar with their use. Portable or furnace-mounted humidifiers were found in some houses.

4.9.2 Heating & Ventilation System Retrofits

Fifty-one of the 83 retrofitted houses had their heating systems replaced during the project. Three major types of retrofits were commonly performed:

- o Replacement of natural gas furnaces or boilers with higher efficiency units.
- o Replacement of oil furnaces with electric units.
- o Replacement of oil furnaces with wood/electric combinations.

A large number of project houses, particularly those in Winnipeg, were heated with forced-air gas furnaces which had been installed 20 to 25 years previously. Since this is the approximate service life of a gas furnace, many of these units were approaching replacement. The opportunity to replace these heating plants with higher efficiency units was therefore favourable. Three major types of high-efficiency gas furnaces were installed:

- o Spark ignition units with flue draft dampers
- o Induced draft units
- o Condensing units

Induced draft and condensing unit replacements were the most common although this was influenced by the Consultants who encouraged several homeowners to consider the higher efficiency units so the entire retrofit package would have a better chance of meeting the program requirements.

A number of random problems were noted with gas furnace replacements. Some of these may have occurred due to installer inexperience since some furnace models had recently entered the provincial market place. Specific types of problems included:

- o Short circuiting between the air intake and exhaust of condensing units which led to inlet icing.
- o Air inlets located too close to grade.
- o Noise and vibration problems with pulse combustion condensing units.
- o Difficulties in securing access to a floor drain to handle the condensate from condensing units.
- o Condensation in the exhaust vents of an induced draft unit caused by a long vent run in a cool basement.
- o Problems with control systems.

Other problems included the venting of gas DHW tanks when the furnace was replaced with a higher-efficiency unit. If a spark ignition with flue-draft-damper unit was installed, the DHW tank vent entered the furnace vent downstream of the flue damper. This reduced the effectiveness of the flue damper since house air was still free to escape past the draft diverter on the DHW tank. With induced draft or condensing units, the furnace vent usually passed through the basement wall.

Another problem which may arise in time is temperature stratification within the living space. This is because most of the furnace replacements did not include a 2-speed blower to circulate air during the off-cycle of the furnace.

Boiler replacements were generally subject to similar problems as forced air furnace replacements. One advantage was that the new boilers were considerably smaller than the units they replaced which made extra

basement area available.

All of the conversions to electric heating were from oil, usually with COSP-assistance. Because of the increased demand of the furnace, the electric service often had to be upgraded to 200 amps. [Note that Energy Demo did not fund gas-to-electric conversions.] All off-oil conversions were to electric forced air furnaces - no duct heaters were installed.

Few problems were encountered with oil-to-electric conversions, probably because of the number which had been performed in recent years.

A large number of oil units were replaced with wood/electric combinations, primarily in rural areas. Although this type of conversion has been relatively common in recent years, safety-related problems were frequently found during the post-retrofit site visits. Again, the main problem was inadequate clearances between the applicance and/or vent and nearby combustible surfaces. Although proper installation procedures are well documented (see for example Ref. 9), there appeared to be a lack of awareness by many installers and homeowners.

The reader considering opportunities for oil-to-electric or oil-to-wood/electric combination unit conversions in Manitoba should be aware that the number of oil-heated houses left in the province is small and continues to shrink. The potential market for further conversions is therefore limited.

Besides heating plant replacements, a number of other, minor mechanical/electrical retrofits were performed. Combustion air ducts were installed in a number of tighter houses to supply air to the heating system and minimize backdrafting. Manual dampers were installed in the ducts to provide some degree of control. Cross-sectional areas were sized to provide 4.4 cm^2 for each kilowatt of furnace input (1 in^2 per 5000 Btu/hr). Construction and installation details were taken from Ref. 10. Virtually all contractors and homeowners were unaware of the potential difficulty of supplying combustion air to houses with low natural air leakage. Another common measure was the installation of a fresh air duct into the return air plenum of the furnace to control humidity levels.

A variety of miscellaneous items were also included in some retrofits such as: automatic setback thermostats, DHW tank insulation, fireplace doors and dampers, exhaust fans and one air-to-air heat recovery ventilator.

Long-term monitoring will be required to determine if excess humidity and other indoor air quality problems will increase in houses which were retrofitted with higher efficiency or electric heating plants (with their reduced demands for outdoor air).

4.9.3 Relative Cost Effectiveness

Conversions to more efficient heating plants were most cost effective in houses with large space heating loads such as poorly insulated, leaky houses since the cost of the retrofit was recoverable against a large heating bill.

Payback Proxies for replacement of existing forced air natural gas furnaces with higher efficiency units were typically in the range of 8 to 16 and did not vary significantly with the type of higher efficiency unit being installed. On this basis, it generally made sense to select the most efficient unit. Payback Proxies for boiler replacements were somewhat higher because of the greater initial cost.

Oil-to-electric conversions typically had Payback Proxies of 2 to 4 with the larger values representing those cases where upgrading of the electrical service to 200 amps was required.

The cost effectiveness of conversions from oil to wood/electric combination furnaces was calculated using electrical and not wood energy costs. Although the rationale for installing a combination unit was to make use of wood as a less expensive fuel source, it was considered impractical and inconsistent to estimate the effects of wood heating because of its varying cost and usage by different homeowners. Using this calculation procedure, Payback Proxies for wood/electric conversions generally ranged from 1.4 to 7.

4.9.4 Summary

- o Upgrading of existing combustion heating plants with more efficient units was found to be most economical in houses with large space heating bills.

- o The relative cost effectiveness of replacing conventional natural gas furnaces with high efficiency units was predicted to be reasonably good. Since many of the existing units were near the end of their service life, the marginal cost effectiveness of upgrading to a more efficient furnace would be even better.

- o Replacement of natural gas boilers with higher-efficiency units was generally less cost effective than forced air furnace replacements because of the higher initial cost. Many of the existing units still had many years of useful life remaining.

- o Replacement of oil furnaces with electric or wood/electric combination units was found to be a reasonably cost-effective measure, especially if the electrical service did not have to be upgraded or if, in the case of wood/electric conversions, an inexpensive source of wood was available.

- o Inadequacies were observed in the installation practices for wood-burning appliances which created potential fire hazards.

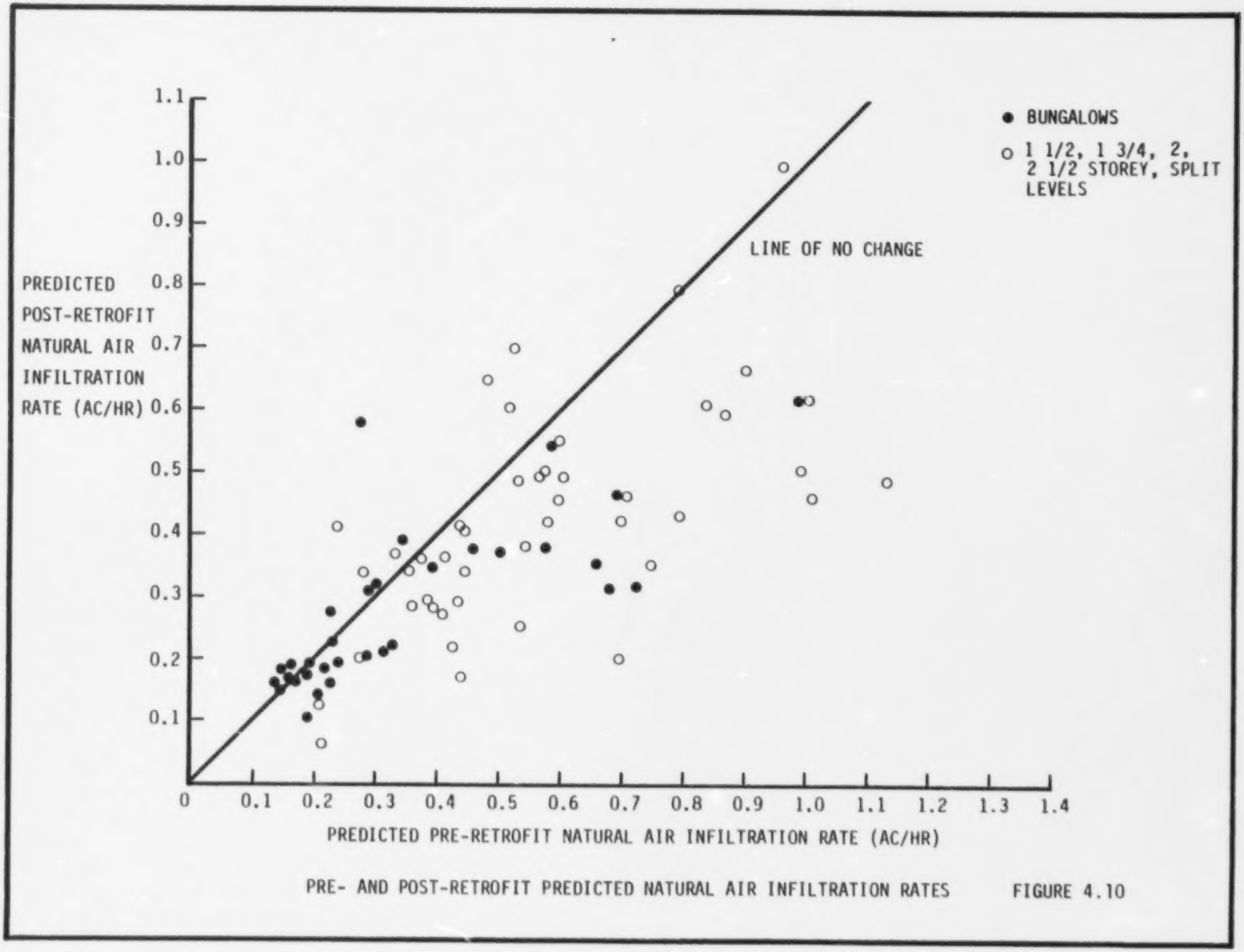
- o Contractors and homeowners were usually unaware of the need to provide adequate air supplies to combustion appliances to minimize potential backdrafting problems.

4.10 OTHER COMMENTS

In addition to those technical and economic aspects of the retrofits presented above, a few related issues deserve comment.

4.10.1 Effects of Retrofits upon the Predicted Natural Air Infiltration Rate

As previously described, the airtightness test results were used to produce estimates of the pre- and post-retrofit natural air infiltration rate for each house. These estimates are shown in Figure 4.10. Single storey houses have been identified separately because they were generally tighter than multi-storey or split level designs. As shown, most houses experienced significant reductions with the greatest changes occurring with



PRE- AND POST-RETROFIT PREDICTED NATURAL AIR INFILTRATION RATES FIGURE 4.10

structures which were initially very leaky.

It should be noted that the results shown in Figure 4.10 represent the net changes in airtightness from all retrofit measures performed on each house and not just air leakage sealing.

4.10.2 Renovation/Repair Considerations

Energy conservation retrofits often require non-energy related work to ensure an effective retrofit. Although the retrofits assisted by the Energy Demo program were restricted to those designed to save energy, many houses were found to require renovation or repair work before energy-related retrofits could be effective. Foundations often required crack sealing to prevent water penetration, wall retrofits could be completed only after replacement of failing structural members, etc.

4.10.3 Increased Resale Value

The previous discussions of the relative cost effectiveness of the various retrofit measures reflected only the direct savings due to reduced energy use. Many of the measures would also increase the resale value of the homes. Those which produced highly visible improvements in the appearance of the structure would possibly have the most pronounced effects. Unfortunately, there is little information available on the actual percentage of retrofit costs which are recoverable at resale. Also, the house-buying public may not distinguish between the various levels of energy conservation. For example a house with a RSI 3.5 wall and one with a (retrofitted) RSI 7.0 wall may both be perceived as "energy-efficient", so that the marginal resale benefits of the energy components (i.e. insulation, air/vapour barrier, etc.) of the retrofit might be minimal.

4.10.4 Increased Property Taxes

On the negative side, the additional value built into a retrofitted house may increase its property taxes. This factor was not considered in the calculation of the relative cost effectiveness of the retrofit measures

for Energy Demo, although it could be quite significant. Once again it is difficult to determine what percentage of the retrofit cost would actually manifest itself in the property taxes. For example, would an assessor recognize that $800 worth of air leakage sealing had been performed on the house? It is recommended that this issue be more carefully investigated.

4.10.5 Utility Demand Savings

To this point, all discussion of costs and benefits has been solely from the perspective of the homeowner. With certain retrofits, there may also be benefits to the energy utilities from reduced system demand if the capacity of the house's heating plant can be reduced. For example, if an electrically heated house were retrofitted its furnace could potentially be reduced in capacity by disconnecting one or more elements. Although detailed consideration of this topic is beyond the scope of this report, the issue is raised for future investigation since its effects could be significant.

SECTION 5
DISCUSSION OF THE ENERGY AUDIT PROCEDURES

5.1 INTRODUCTION

During the Energy Demo program, a total of 154 houses received energy audits. This section of the report discusses the energy audit procedures and the HOTCAN simulations and offers some general conclusions and recommendations on residential energy auditing.

5.2 ENERGY AUDITS

The energy audit procedures evolved over the course of the program to incorporate the experiences from the initial audits for improvement of the overall performance of the program. The discussion which follows represents the final and not the interim techniques which were employed.

5.2.1 Scheduling

As discussed in Section 3 the audit process began with the forwarding of a file from Energy & Mines to the Consultants containing the homeowner's original application for the Energy Demo program plus any relevant correspondence and administrative notes. The file was held by the Consultants until an audit team became available - typically one to eight weeks. The homeowner was then contacted to schedule the date and time of the audit. As expected, scheduling within Winnipeg, where the Consultants were based, was not a major obstacle whereas rural and northern scheduling often created major problems. Audits were performed Monday to Saturday, and most were carried out during normal working hours although some rural audits had to be performed in the evenings.

5.2.2 House Visit

House visits were performed by a one or two man audit crew consisting of an engineer or architectural designer with a technician to perform the airtightness test. Some visits in rural or remote areas were performed by a one man crew. Each member of the crew had two to eight years of

experience in residential building technology.

Upon arriving at the house and making introductions to the homeowner, one member of the crew conducted an examination of the structure. He generally familiarized himself with the house, collected data required for the HOTCAN simulations (dimensional data, component construction, insulation levels, etc.) and identified opportunities for retrofit work. Although this last item was ostensibly the responsibility of the homeowner, it was found that most applications benefited from some guidance. The house examination was conducted according to a standardized checklist which identified the major features of the house, the need for possible repair work and the lifestyle of the occupants. Although the audit procedures evolved into a standardized process by the end of the program, checklists were used throughout the program to ensure uniformity. A sample copy of the forms and checklists is included in Appendix A.

Special emphasis was placed on identifying possible indoor air quality problems. A rough assessment was first performed to determine if an air quality problem existed in the pre-retrofit house. The possible repercussions of the proposed retrofit upon the indoor air quality were then estimated. Conclusions were then conveyed verbally to the homeowner. Assessment of the initial air quality was performed by consultation with the homeowner and direct observation of the state of the structure, particularly the heating and ventilation system. No direct air quality measurements were performed. Evaluation of the possible effects of the retrofit required consideration of several factors including: a) the estimated existing air quality, b) the existing air leakage, c) the type of proposed retrofit, d) the types of materials to be used in the retrofit, e) the anticipated change in the air leakage, f) the type of heating system and g) the occupant's lifestyle. The number and interrelation of the variables involved required the auditors to make qualitative judgements based on their experience. Once the possible consequences of the retrofit had been estimated, the homeowner was advised either on-site during the initial audit or later by telephone. Due to the wide range of possible responses, it is difficult to describe the advice which the homeowners

received. In general, most of the retrofits involved changes which could affect the air quality either by reducing the natural air infiltration rate or decreasing the air supply to the furnace. When there was concern about insufficient air supply, the installation of a fresh air duct to the return air plenum was recommended. In houses without forced air heating systems, the homeowner was advised to take steps to isolate and remove the contaminants at their sources by installing exhaust fans. In those cases where there was concern about the adequacy of the furnace air supply, installation of a combustion air duct was recommended.

Once the auditor had collected the necessary data, the original retrofit proposal was reviewed with the homeowner. In the majority of cases, the auditor was able to make suggestions to improve the cost effectiveness of the proposal. The auditor also reviewed the administrative details of both the Energy Demo program and other federal or provincial grant programs (such as CHEC, CHIP, COSP, RRAP, etc.). Grant programs often proved a source of confusion to homeowners.

Often, the homeowners queried the auditors on renovation or repair work which the house might require before the proposed retrofit could be performed.

While the above activities were taking place, the second crew member performed the airtightness test. Once the measured test was completed the house was depressurized and an examination carried out of potential air leakage sources. These were summarized on a checklist (see Appendix A) and a copy was left with the homeowner. Since the homeowners were usually present during the test, they were encouraged to examine the house while it was depressurized. Most had believed that air leakage was restricted to doors and windows, thus the examination often proved to be an enlightening experience and helped to convince them of the significance of other leakage sources.

The only major problem encountered during the airtightness tests was the inability to generate sufficient pressure differentials in some very leaky houses. In such cases, the airtightness data had to be collected over a less-than-desirable range of pressure differentials.

Furnace efficiency tests were not included in the energy audit because the steady state efficiency (which the test determined) was not considered to be of sufficient value to the Energy Demo program objectives to justify the cost. Generally accepted values for the seasonal efficiencies of heating plants were used, occasionally with some modifications to reflect the apparent condition and hence performance of the unit. A summary of the seasonal efficiencies used is shown in Figure 5.1.

As expected, most homeowners were very interested in the findings of the energy audit. Most, however, were more concerned with the non-quantitative conclusions of the audit, i.e. those dealing with "what" to do, "how" to perform the work, "why" to follow a particular procedure, etc. Details relating to projected energy savings, payback periods, etc. were held to be of secondary importance.

5.2.3 HOTCAN Analysis of Retrofit

Using the data collected during the house visit, the HOTCAN simulations were performed. HOTCAN was selected as the analysis program because of its reasonable accuracy and ease of use. Further details on the program can be found in Ref. 11. All simulations were performed using a FORTRAN version of the program run in a batch format on a mainframe computer. The following simulations were typically run:

- o The house in its pre-retrofit or "base case" condition with standardized inputs for temperatures, appliances and DHW usage.
- o Separate runs for each major conservation retrofit measure proposed by the homeowner or suggested by the Consultants.
- o Various combinations of individual retrofit measures.

Typically 10 to 25 simulations were run for each house.

Once the simulations had been completed, the performance and cost effectiveness of each retrofit measure and their various combinations were analysed. Utility records or fuel bills, when available, were used to check the simulations. Frequently, however, complete records were not available in time or, in the case of farm houses, could not be

FIGURE 5.1

SEASONAL EFFICENCIES OF HEATING SYSTEMS

FUEL	HEATING SYSTEM	SEASONAL EFFICIENCY'
Oil	Conventional	60% to 65%
Oil	Conventional with flame retention head	70%
Oil	High efficiency	80%
Oil/Electric	40%/60% hybrid	Seasonal efficiency +5%
Oil/Electric	10%/90% hybrid	Seasonal efficiency -5%
Gas	Conventional	60% to 65%
Gas	Power burner conversion from oil	65%
Gas	Electric ignition and flue damper	75%
Gas	Induced draft	83%
Gas	Condensing	90%

Notes:

1. Values shown were used as guidelines for use in the HOTCAN analysis of project houses. Some adjustments to these values were made based on the observed condition and hence performance of the heating system.

distinguished from the non-residential energy usage. The use of wood heating further confused the significance of the utility records because wood energy consumption was not generally recorded and was difficult to estimate.

5.2.4 Homeowner Review

Once the analysis had been completed, the homeowner was re-contacted by telephone to discuss the results. Any changes to the application, based on the results of the simulation, were discussed and agreed upon if possible.

5.2.5 Documentation

A summary of the energy and cost analysis and the house's ability to meet the Energy Demo program requirements was then prepared and forwarded to Energy and Mines. They were responsible for the decision and subsequent notification of the homeowner of proposal acceptance or rejection.

5.3 HOTCAN MODELLING

The 10 to 25 separate HOTCAN simulations which were performed on each of the 154 project houses provided some interesting insights on residential energy modelling.

5.3.1 Need for Trained Users

The computer modelling experiences clearly demonstrated the need for trained personnel to perform such work. In many cases, judgment was required to estimate input variables and to interpret or correct the final results. Despite several years of experience in residential building technology, which included HOTCAN modelling, the Consultants were in some cases unable to obtain reasonable matches between the HOTCAN results and the energy bills.

5.3.2 Input Uncertainties

Aside from the inherent limitations of the modelling process, other input data uncertainties restricted the accuracy of the results. The most significant of these were:

1. Defining component construction - In several cases, the construction of individual building envelope components could not be determined because of a lack of access. Common problem areas were the attics of 1 1/2, 1 3/4 and 2 1/2 storey houses and most exterior walls.

2. Estimating R-values - Even when the nominal construction of the envelope component was known, the actual R-value was occasionally difficult to determine due to insulation settlement, possible wetting or other damage. Another major inaccuracy may have been caused by snow build-up against foundation walls which increased the effective R-value. It was also common practice for some homeowners to pile snow against the foundation walls to reduce heat loss. This could produce a major error in the simulation since an uninsulated above-grade foundation wall can be responsible for a significant portion of the total house heat loss.

3. Heating system efficiency - The values used for the seasonal efficiency of the heating system were based on generally accepted data with modification in some instances to reflect the observed condition of the system. Although these values were judged reasonable for a large sample group, significant variations between assumed and actual efficiencies may have occurred for individual houses.

4. Estimating actual house temperatures - Although detailed analysis of the predicted space heating loads was beyond the scope of this project, casual comparisons between available utility records and the HOTCAN simulations indicated a tendency for HOTCAN to overestimate actual loads and hence the possible savings attainable from the retrofits. Although there may be several reasons for this, the most significant is believed to be caused by overestimates of the actual temperature differences across the building shell. In many houses the heat distribution system was incapable of maintaining uniform temperatures throughout the interior. With the low R-values of some envelope components the effective temperature difference across these components would have been lower than assumed by HOTCAN. Further, few homeowners had an accurate perception of the average inside temperature at which their house was maintained. Although they were generally

aware of the thermostat setting (which may itself be inaccurate) and could identify whether significant temperature variations existed throughout the house, they were usually unable to estimate actual temperatures in areas such as the basement or infrequently used rooms. As a result, the net heat loss and hence savings possible from retrofitting were less than predicted.

It should be noted that these input uncertainties are believed to be common to other simulation programs.

5.3.3 Energy Balances

If complete utility records were available, the actual and predicted consumption figures could have been balanced by modifying the input data. During Energy Demo, the records were usually not available. However even if they had been, considerable caution would have been necessary. Considering that several potentially significant uncertainties existed, there would have been uncertainty as to which variable(s) should have been adjusted. Further, even when a balance had been obtained, the auditor would have had to consider the possibility of compensating errors existing in the input data. Cumulative discrepancies in energy balance variables could have led to large errors in the simulation of the proposed retrofit.

5.3.4 Suitability of HOTCAN for Analysing Existing Houses

HOTCAN was originally developed as a tool for predicting the energy consumption of low-energy houses. Because of the better heat distribution systems and higher insulation levels in these structures, interior conditions tend to be more uniform and thus more representative of the values used as input than in conventional houses. Based on the preceding discussions, it is apparent that "defining" the actual thermal resistances, interior temperatures and heating system efficiencies may be considerably more difficult for older, poorly insulated houses. As a result, the accuracy reported for HOTCAN, determined largely by monitoring low-energy houses, may not be applicable to older structures. It may be desirable to modify some of the program's algorithms or provide special user input instructions for modelling existing houses.

5.4 SUMMARY

- The major benefits of an energy audit to the homeowner appear to be the qualitative information which is received and not the more precise quantitative data.
- Energy auditors require a comprehensive understanding of all aspects of house design including construction practices, heating and ventilation systems, occupancy use characteristics, indoor air quality as well as a thorough knowledge of energy conservation practices.
- The energy auditor must have a realistic appreciation of the accuracy and limitations of any energy analysis procedures or computer programs which are used.
- A good energy audit can be described as one which takes a balanced, realistic approach and recognizes the construction of the house and the lifestyle, interests and budget of its occupants.
- Significant simulation input errors may result from incorrect estimation of building component construction, component R-values, heating system efficiency and actual indoor temperatures.
- Further research is needed to determine the accuracy of HOTCAN for analyzing the heating loads of existing houses constructed to comparatively low standards of energy conservation.

SECTION 6
OBSERVATIONS ON HOMEOWNER AND CONTRACTOR KNOWLEDGE OF RESIDENTIAL ENERGY CONSERVATION

6.1 INTRODUCTION

During the Energy Demo program, numerous conversations were held with homeowners and contractors to discuss the retrofit projects. Although no formal survey was performed, casual observations offerred some interesting insights into their knowledge of energy conservation.

This section of the report contains a summary of these observations and identifies some areas where public and contractor knowledge could be improved. These observations are offered for the benefit of those who are involved with information transfer to the general public and the industry.

6.2 HOMEOWNERS

Homeowners who participated in Energy Demo did not represent a random cross section of the general population. They usually had an above-average interest in residential energy conservation and often had completed extensive personal research and were eager to acquire more knowledge. Further, many of the homeowners had objectives influencing their decision-making process which went beyond energy conservation. Many were interested in improving the appearance of their homes or raising comfort levels. Nonetheless, the project experiences suggest some major deficiencies in homeowners' understanding of residential energy conservation.

The most poorly understood area was the relative cost effectiveness of various conservation measures. Homeowners frequently proposed retrofits or retrofit measures with extremely high Payback Proxies while ignoring opportunities for very cost-effective retrofits. The classic example was the desire of many homeowners to replace existing doors and windows which were in relatively good condition while ignoring sections of the foundation which were completely uninsulated. Some homeowners appeared to believe that the dominant source of heat loss was through the windows. Therefore

upgrading windows was believed to produce major energy and dollar savings. It is uncertain whether this misunderstanding resulted from the absence of good technical information on the subject, the heavy advertising by window manufacturers or the obvious drafts and high temperature gradients in the vicinity of windows.

This point is illustrated by Figures 6.1 and 6.2 which summarize the occurence of the various retrofit measures as originally proposed by the homeowners and as eventually constructed after the energy audit had been performed. Only data from the 83 retrofitted houses is included in the figures. In all cases, the data shows the net occurrence and does not account for compensating additions and deletions of measures on individual houses. If the "as-built" occurrences are assumed to represent, or at least approximate, a "reasonable" retrofit, then the difference between these and the "as proposed" occurrences provide a rough indication of the ability of the homeowner to identify appropriate conservation measures. For example, the application of exterior insulated sheathings to walls and the replacement of windows, particularly in post-1945 houses, were much more popular than found to be actually justified. Replacement of heating plants, on the other hand, were not as frequently proposed by the homeowners as analysis indicates they should have been.

Another poorly understood area was the concept of diminishing returns. Some homeowners appeared to believe that the benefits of adding extra insulation were independent of the existing insulation level. For example, the application of RSI 2 insulation to a wall already heavily insulated was thought to produce the same benefits as adding the insulation to an uninsulated basement wall.

A very common belief was that heating systems, doors and windows were inefficient by virtue of their age. In some cases this was, of course, true but in other instances it was quite incorrect, such as with cast iron boilers or doors and windows in good repair. Minor problems were also encountered with some homeowners in the use of metric measurements. Virtually all preferred or insisted upon imperial units.

FIGURE 6.1 CONSERVATION RETROFIT MEASURE OCCURRENCES IN PRE-1945 HOUSES

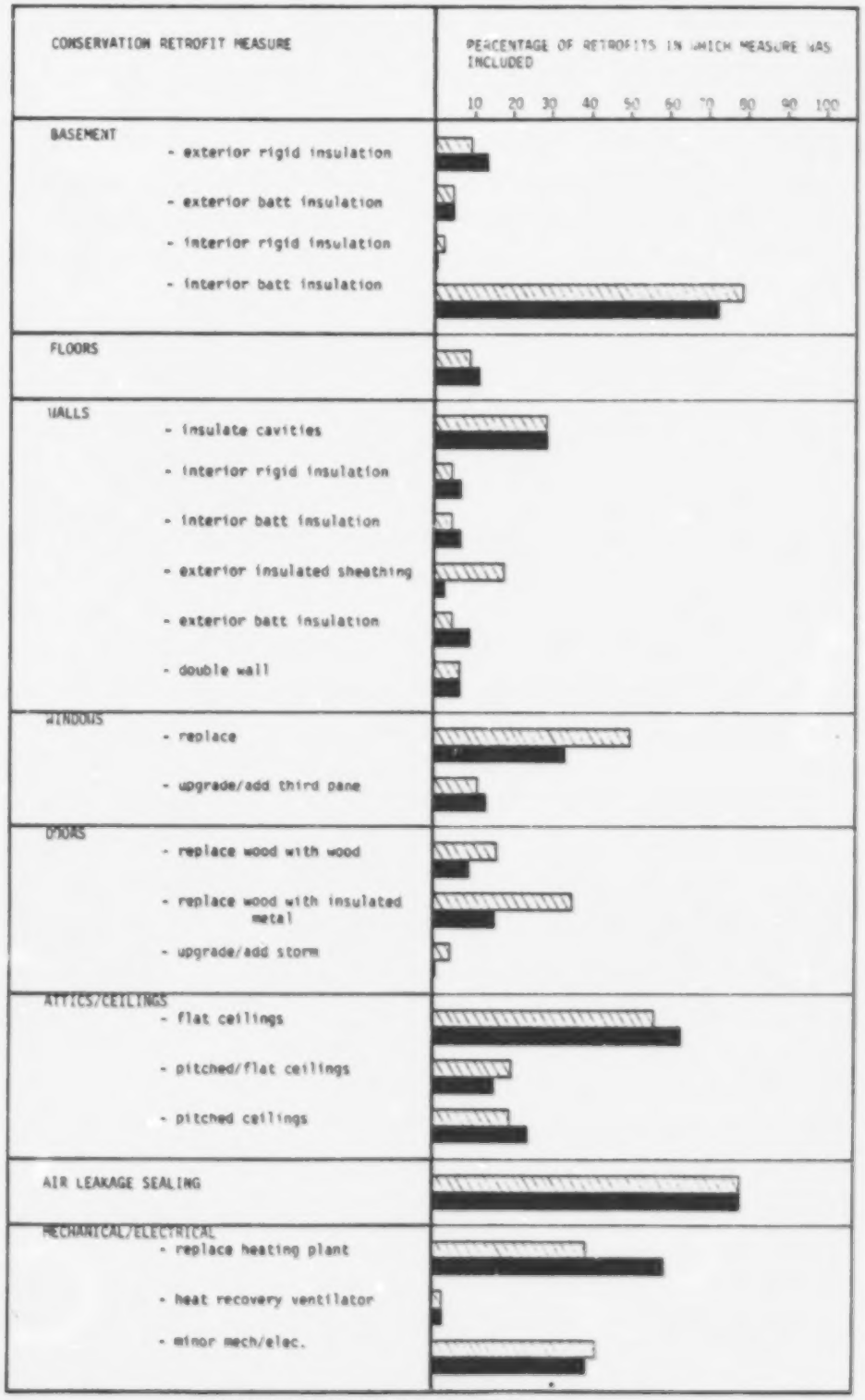
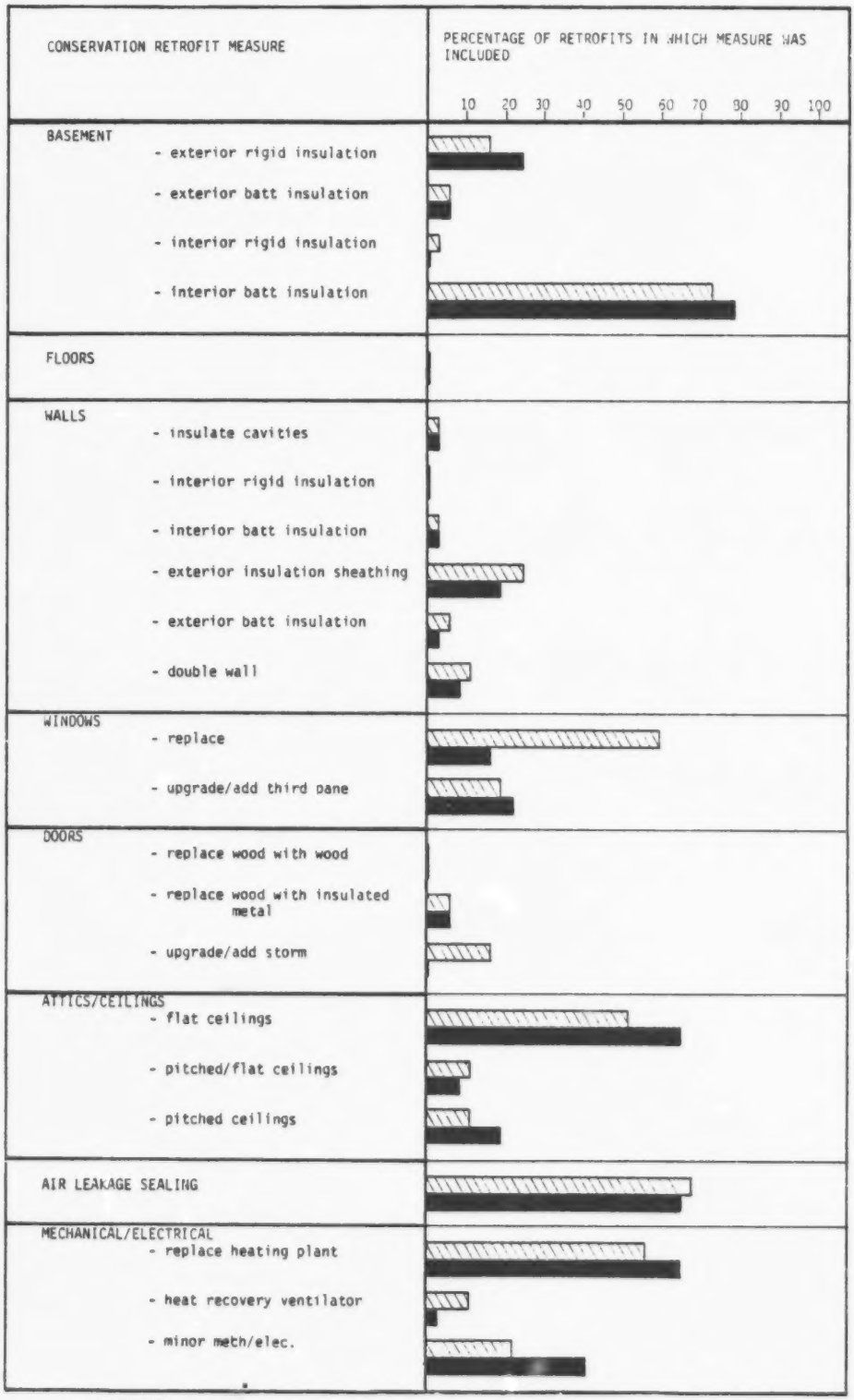


FIGURE 6.2 CONSERVATION RETROFIT MEASURE OCCURRENCES IN POST-1945 HOUSES



Other examples of poor understanding or misconceptions included:

Foundations

- Heat loss through below-grade portions of foundation walls was believed to be relatively insignificant ("the earth acts as an insulator"?).
- Insulation of foundation walls was viewed as only being required part way down the wall.

Exterior Walls

- The exterior walls of older homes were generally considered to be uninsulated. In several cases the homeowner was emphatic that there was "no insulation in the walls" and yet when access holes were drilled, insulation, usually wood shavings in good condition, was found. Some homeowners may not consider wood shavings to be insulation.
- Many homeowners believed that a major source of heat loss was the exterior walls even if the exterior walls were relatively well insulated.

Doors and Windows

- A very common belief was that doors and windows were the major source of air leakage and a dominant source of heat loss.
- Some homeowners were not aware that many doors and windows could be successfully retrofitted at reasonable cost.
- Few homeowners understood the need to seal interior storms and vent exterior storms.

Attics and Ceilings

- There was a belief that very high levels of insulation were required in the attic or ceiling because "heat rises" and thus most heat loss was assumed to occur through the attic or ceiling.
- Some homeowners did not believe that wood shavings provided any benefit as thermal insulation and were therefore willing to accept statements that their attic was "uninsulated".

- Roof-mounted turbine vents were seen as the "solution" to possible condensation problems in the attic. Very few homeowners understood the proper moisture and ventilation control measures.

Air Leakage Sealing

- Most homeowners believed that air leakage through doors and windows was the major or only source of air leakage in a house. They were generally surprised during the airtightness test to discover how much leakage was occurring through other sources.

- The majority of homeowners believed that their house would benefit from air leakage sealing. In many cases this was correct, but in a number of instances the houses displayed obvious signs of having low natural air infiltration rates. This belief could have serious implications with indoor air quality and furnace backdrafting.

- Homeowners were unaware that air leakage sealing of interior surfaces of the building envelope could provide protection against possible living space-generated moisture damage.

- The various issues dealing with indoor air quality were seldom recognized or understood.

Heating and Ventilation Systems

- Homeowners were generally unaware of the service life of their heating system. Many believed that existing boilers had to be replaced because they were "old" or that 20 year old natural gas furnaces had many years of useful life remaining.

- Virtually all homeowners were unaware of potential problems with furnace backdrafting and the need to supply adequate amounts of combustion air to the heating system.

- Most homeowners were unaware of how to control the relative humidity in their houses by proper ventilation or seasonal adjustment of the fresh air duct damper.

6.3 CONTRACTORS

Approximately 100 different contractors worked on Energy Demo retrofits. In general their backgrounds were extremely varied. Some, had taken the CGSB course on insulating houses for energy conservation, others had taken various training courses on specialized topics from product manufacturers or distributors. Others had little if any formal training in residential energy conservation and were essentially general contractors willing to undertake a broad range of work.

Contractor selection was the responsibility of the homeowner. Some were selected on the basis of their quotations and perceived ability to complete the job, others were simply hired through a personal relationship with the homeowner. Experience levels ranged from a few years of general contracting duties to several decades of very specialized work.

Most of the firms were relatively small in size, characterized by having less than 10 permanent employees. A few firms were able to successfully bid on several Energy Demo retrofit projects, indicative of their size or marketing capabilities.

As expected, the quality of workmanship varied from excellent to poor. Many contractors went to great lengths to ensure the work was performed properly and to the satisfaction of the homeowner. Others appeared less conscientious, indicative of either their personal performance standards or their technical understanding. The trades which displayed the highest standards were heating contractors, possibly because the trade is comparatively heavily regulated and their work is subjected to regular inspection.

Some small differences were apparent in the capabilities of rural versus urban contractors. Urban contractors tended, on the most part, to be more specialized whereas rural contractors were willing to undertake a much broader range of work. Urban contractors were more likely to have personnel designated as salesmen.

Many contractors, especially those dealing with general construction and carpentry, displayed a poor appreciation of the cost effectivenesses of various conservation measures. This may have reflected their previous work

experiences. For example, a carpenter who may have framed and insulated several hundred basements would have viewed his primary purpose as being creation of additional living space within the house. The fact that insulation was included in the retrofit was viewed as a side benefit. In contrast, that same carpenter, on being hired to insulate a basement to reduce heat loss, may not have appreciated the differences in emphasis for the "new" task.

Another problem frequently observed was that few contractors or their sales representatives conducted adequate examinations of the house prior to drawing up the detailed work statement, contract and price. In such cases the contractor made major assumptions regarding the house's conditions and then acted on the basis of those assumptions. For example, several homeowners received quotations for wall insulation when examinations revealed that the wall cavities were already insulated. In one case, the contractor quoted a price of almost two thousand dollars for exterior wall insulation because the homeowner was convinced that a house of that period would not contain any insulation. Removal of some siding revealed wood shavings in excellent condition. Contractors often quoted on upgrading attic insulation levels in 1 1/2, 1 3/4 and 2 1/2 storey houses without having gained access to the attic area. Air leakage sealing was frequently recommended by contractors, even in cases where the house displayed obvious signs of inadequate natural infiltration. It should be acknowledged that conducting thorough house examinations is often an expensive and tedious task. Most contractors could not afford specialized equipment, such as a borescope, which would aid them in this task. Unfortunately, most contracts between the homeowner and the contractor did not contain contingency provisions to permit deviations if the original assumptions used to price the work proved to be in error.

Related to these problems was the absence of computational ability to estimate the energy and dollar savings from retrofit measures. As a result contractors relied upon general information on energy conservation found in popular literature. Considering the very unique characteristics of individual houses this often led to significant errors in perception of

benefits.

There was also a tendency for some contractors to recommend one particular solution rather than considering alternatives which might be more attractive. For example, a common recommendation for exterior wall retrofits was the addition of extruded polystyrene and vinyl siding even in situations where other types of retrofits would have produced superior results.

Few contractors displayed an understanding of the importance or significance of indoor air quality and potential backdrafting problems from combustion appliances. This was possibly because these areas do not fall within the domains of any standard trades. Most contractors displayed a minimal concern for those aspects of the job which might affect other trades.

A wide variation in detail in the quotations which contractors submitted to the homeowners was also observed. Some provided extremely detailed breakdowns of the work tasks while others provided only a few lines with the most cursory explanation. There did not appear to be any relationship, however, between the detail of the quotation and the quality of the finished product.

SECTION 7
TECHNOLOGY TRANSFER

7.1 INTRODUCTION

The Energy Demo program was the first major demonstration of residential energy conservation retrofitting in Manitoba. It provided technical and economic information on the various conservation alternatives and also offered practical experience with the management and administration of residential energy audit programs.

As previously mentioned, much of the direct technical knowledge has already found application beyond the program. For example, Manitoba Energy & Mines has incorporated some of this information into the literature on energy conservation which it distributes to the general public.

In addition, the experiences of Energy Demo found direct and immediate application in two subsequent energy conservation projects delivered in Manitoba: the T.E.A.M. (Town Energy Audit Match) project and the Home CHEC-UP (Cut Home Energy Costs) program. To place this report in a proper context, a summary of all three programs follows.

7.2 ENERGY DEMO

Energy Demo provided intensive energy audits to a relatively small number of houses using personnel with several years of previous experience in residential building technology. A total of 154 houses were audited. Of these 83 were retrofitted using a variety of conservation strategies to produce a minimum reduction of 40% in each house's predicted energy consumption. The retrofitted houses were also monitored during construction to identify problems, solutions, etc. Post-retrofit site visits and airtightness tests were performed on all 83 houses. The program provided information on the technical viability of various conservation alternatives and established a data base on the costs of these measures using actual construction quotes. It also provided information on audit procedures, program administration, management, information transfer, and the public's understanding of energy conservation.

7.3 T.E.A.M. PROJECT

The Town Energy Audit Match (T.E.A.M.) project was a multi-sector demonstration of energy conservation applied to two towns (Stonewall and Pinawa, Manitoba). It was also delivered under the Conservation and Renewable Energy Demonstration Agreement. One of the major components of the project was the provision of residential energy audit services, free of charge, to all homeowners who requested them in the towns. Using the experience gained during Energy Demo a program was established in which 24 energy advisors were hired and trained specifically to provide auditor services in the two towns. The scale of delivery services was more widespread than Energy Demo. T.E.A.M. also required a more developed management and administrative system to handle the audit delivery services. A total of 641 houses were audited during the program.

7.4 HOME CHEC-UP

Using the experiences from Energy Demo and T.E.A.M., Home CHEC-UP was established as a province-wide residential energy advisory service available to all Manitoba homeowners. Using the technical information gained during the previous two programs, coupled with the experiences on program delivery, Home CHEC-UP is now functional. It currently has the capacity to deliver approximately 4,000 energy analyses per year. The program is delivered by Manitoba Hydro and is funded by Manitoba Energy & Mines.

A summary of these three programs is shown in Figure 7.1.

FIGURE 7.1

SUMMARY OF ENERGY DEMO, T.E.A.M. AND HOME CHEC-UP PROGRAMS

	Energy Demo	T.E.A.M.	HOME CHEC-UP
Type of Program	Once-only (1983-84)	Once-only (1983-84)	On-going (1984 -)
Eligibility for Audit	Restricted to specific types of houses	Restricted to houses in specific towns	Open, province-wide
Types of Audits	Intensive - multiple computer simulations - auditor site visits before, during and after retrofit work - pre and post-retrofit air-tightness tests	Medium - hand calculations - no site visits during any retrofit work - no airtightness tests	Medium - hand calculations - no site visits during any retrofit work - no airtightness tests
Number of Audits Performed	154	641	Capacity of 4,000 per year
Number of Retrofits Funded By Program	83	6	0
Number of Auditors/ Advisors	3	24	24
Related Previous Experience of Auditors/Advisors	Considerable	Minimal	Minimal

SECTION 8
SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

GENERAL

- The Energy Demo program provided valuable information on the technical, economic, and practical aspects of retrofitting existing houses and generated a data base on the costs and benefits of the various conservation measures. It also provided valuable insights into the general understanding of homeowners and contractors of residential energy conservation.

- The greatest opportunities for cost-effective reductions in energy use were found to be: the addition of insulation to poorly insulated building components such as foundations, empty exterior wall cavities and poorly insulated attics; air leakage sealing of houses with excessive air leakage; and the replacement of heating plants with more efficient units.

- Potentially positive side effects of energy conservation retrofits were found to include:

  - Significant improvements in the comfort levels of houses due to more uniform temperatures, reduced drafts, improved humidity levels and reduced noise levels.

  - Increases in the usable living space for some types of retrofits.

  - Improvements in the appearance of houses.

  - Increased resale value.

- The economic benefits of energy conservation retrofits could be seriously eroded if property taxes were to increase significantly as the result of the retrofit.

- Savings from energy conservation retrofits may be less than predicted because of the higher temperatures at which houses will be maintained after their retrofits. Considering the significance of this point, it is recommended that additional field data be collected to quantify better the actual savings from energy conservation retrofits.

- Energy conservation retrofits could potentially have positive benefits for energy utilities due to reduced system demand. It is recommended that the implications of conservation upon utility demand be investigated in more detail.

FOUNDATION RETROFITS

- Retrofitting of foundations which had previously been uninsulated was predicted to be a relatively cost-effective means of saving energy. However the savings may be offset in some cases by the significantly higher temperatures at which the basements may be maintained after the retrofit.

- Side benefits from foundation retrofits included increased comfort levels, improved appearance of basement spaces and increased foundation stability in some cases.

- The most significant potential problems encountered with foundation retrofits were the creation of cold floors along the main floor perimeter caused by insulation of the header areas and the increased difficulty in detecting and repairing foundation cracks because of the presence of the insulation.

EXTERIOR WALL RETROFITS

- The application of insulation to empty wall cavities was predicted to be relatively cost effective.

- Retrofitting of exterior walls using other techniques such as the application of rigid insulation, strapping, single or double walls was predicted to be significantly less cost effective. These types of retrofits were found to be most economical when the house was due for re-siding or the interior finish was in need of replacement.

- Exterior wall systems required careful examination to determine existing insulation levels before proceeding with any retrofit work.

- Exterior wall retrofits required careful planning to consider the possible relocation of utility lines, available overhangs, lot setbacks and structural detailing.

- Interior and exterior wall retrofits usually produced significant improvements in the appearance and possible resale value of the house.

WINDOW RETROFITS

- The relative cost effectiveness of replacing double-glazed windows with new triple-glazed units was extremely poor. Such retrofits were only warranted on aesthetic grounds or if the units were physically in need of replacement.

- o Third pane storm window retrofits were much more cost effective than complete replacement and were the most economical means of controlling window condensation.

- o Excessive air leakage through existing windows was most economically corrected using proper air leakage sealing techniques.

DOOR RETROFITS

- o The replacement of existing doors in good or reparable condition with energy-efficient units was predicted to have a very poor relative cost effectiveness.

- o The marginal cost effectiveness of replacing existing doors with more energy-efficient designs was usually predicted to be reasonable when the existing doors had to be replaced for other reasons.

- o Many doors which homeowners viewed as requiring replacement were successfully and economically retrofitted by proper weatherstripping and sealing.

ATTIC AND CEILING RETROFITS

- o Attic retrofits in bungalows and 2 storey houses were relatively cost-effective provided the initial insulation level was low.

- o Attic and ceiling retrofits in 1 1/2, 1 3/4 and 2 1/2 houses were less cost effective than bungalow and 2 storey retrofits. They were most economical when major interior renovations were being carried out to the upper levels of the house. Particular emphasis had to be placed on sealing of the floor joist penetrations into the attic spaces.

- o Cathedral ceiling retrofits exhibited a relatively poor cost effectiveness and were best performed when other repairs, such as replacement of the shingles, were required.

- o Attics and ceiling retrofits required consideration of three steps to be successful: air leakage sealing, the addition of extra insulation and increased ventilation.

AIR LEAKAGE SEALING RETROFITS

- o Based upon subjective estimates of the change in airtightness, the relative cost effectiveness of air leakage sealing retrofits were predicted to be very good, especially if the work was performed by the owner.

- Higher comfort levels due to reduced drafts and better protection of the building shell due to reduced water vapour penetration were also anticipated.

- Notwithstanding the above, indiscriminate air leakage sealing could lead to serious problems with indoor air quality and the supply of air to combustion appliances. Many houses would not have benefited from air leakage sealing. It is recommended that better guidelines, standards and testing procedures be developed for contractors, homeowners and energy advisors to safeguard indoor air quality. It is further recommended that steps be taken to identify the magnitude of this problem in Manitoba houses.

- The blower door was found to be a valuable aid in the identification of air leakage areas.

HEATING AND VENTILATION SYSTEM RETROFITS

- Upgrading of existing combustion heating plants with more efficient units was found to be most economical in houses with large space heating bills.

- The relative cost effectiveness of replacing conventional natural gas furnaces with high efficiency units was predicted to be reasonably good. Since many of the existing units were near the end of their service life, the marginal cost effectiveness of upgrading to a more efficient furnace would be even better.

- Replacement of natural gas boilers with higher-efficiency units was generally less cost effective than forced air furnace replacements because of the higher initial cost. Many of the existing units still had many years of useful life remaining.

- Replacement of oil furnaces with electric or wood/electric combination units was found to be a reasonably cost-effective measure, especially if the electrical service did not have to be upgraded or if, in the case of wood/electric conversions, an inexpensive source of wood was available.

- Inadequacies were observed in the installation practices for wood-burning appliances which created potential fire hazards. Since improper installation can pose a significant fire hazard, it is strongly recommended that efforts be initiated to insure better installation practices through improved training, public and contractor education, and inspections.

- Contractors and homeowners were usually unaware of the need to provide adequate air supplies to combustion appliances to minimize backdrafting problems. It is recommended that better training, education and inspections be initiated to minimize this problem.

RESIDENTIAL ENERGY AUDIT PROCEDURES

- Homeowners were most concerned with the qualitative results of the energy audit. Issues such as "which" measures to undertake, "how" to perform a particular measure, "why" to include a particular step were of primary importance. The more precise quantitative results dealing with energy savings, payback periods, etc. were of less interest despite their significance for gaining admission to the program. If these experiences are representative of the public's interest, it is recommended that residential energy programs resist the temptation to overemphasize analytical capabilities but rather concentrate on the qualitative aspects of the audit.

- Energy auditors require a comprehensive understanding of all aspects of house design including construction practices, heating and ventilation systems, occupancy use characteristics, indoor air quality as well as a thorough knowledge of energy conservation practices.

- The energy auditor must have a realistic appreciation of the accuracy and limitations of any energy analysis procedures or computer programs which are used.

- A good energy audit can be described as one which takes a balanced, realistic approach and recognizes the construction of the house and the lifestyle, interests and budget of its occupants. Homeowners were quite appreciative of the impartial advice from the energy audit and were willing to adopt most of the recommendations (although the desire to gain admission to the program and its benefits may have also been a factor).

- Further research is needed to determine the accuracy of HOTCAN for analyzing the heating loads of existing houses constructed to comparatively low standards of energy conservation. Casual comparisons between utility records and HOTCAN predictions of energy usage suggested that the program tended to overestimate space heating loads and hence the savings possible from retrofitting. The reasons for these overpredictions are believed to be the significant horizontal and vertical temperature stratification which exists in many older, poorly insulated, leaky houses coupled with the difficulty of establishing actual R-values of many building components and the seasonal efficiencies of heating plants. This suggests the need for modifications to the program and better training for its users when it is applied to existing structures.

HOMEOWNER AND CONTRACTOR KNOWLEDGE OF RESIDENTIAL ENERGY CONSERVATION

- o The understanding of appropriate residential energy conservation measures and techniques shown by most homeowners and some contractors was generally poor even considering that homeowners in the project likely had above average knowledge of the subject. A variety of misunderstandings and misconceptions relating to energy conservation displayed by homeowners and contractors were noted.

- o Homeowners and contractors often failed to conduct thorough and proper examinations of the house to determine existing insulation levels. Coupled with an apparent inability to identify and priorize the conservation alternatives, most of the originally proposed retrofits had a poor cost effectiveness. Further, the "grass roots" creativity for finding novel, yet practical, solutions to saving energy was seldom evident. In most cases, homeowners relied on popular literature or the advice of the contractor.

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GLOSSARY

ADFREEZING - The process by which soil freezes to a foundation wall thus permitting vertical movement of the soil to be transferred to the wall.

AIRTIGHTNESS TEST - A test performed to measure the ability of the house envelope to resist air infiltration.

BACKDRAFTING - Flow reversal in, or spillage from, an exhaust vent caused by a negative indoor-to-outdoor pressure differential. Most frequently refers to furnace backdrafting, which can permit the products of combustion to enter the house.

BALLOON FRAME CONSTRUCTION - A method of wood frame construction in which the studs extend in one piece from the foundation wall to the top plate supporting the roof. (Ref. 12) (see PLATFORM FRAME CONSTRUCTION)

BLOWER DOOR - The device used to perform an airtightness test.

BORESCOPE - An optical device which permits the interior of enclosed spaces, such as wall cavities, to be viewed by inserting a probe through a small access hole into the space.

CAST-IN-PLACE FLOOR SYSTEM - A method of attaching the floor system to the foundation wall in which the floor joists and headers are set into pre-notched foundation forms and the concrete poured so that the floor system is permanently cast into the wall.

CHEC - Cut Home Energy Costs.

CHIP - Canadian Home Insulation Program.

COSP - Canada Oil Substitution Program.

DIFFERENTIAL SETTLEMENT - The non-uniform settlement of a foundation after construction is completed; can produce cracking of the foundation or tilting of the house.

EFFLORESCENCE - Formation of white crystalline deposits on the face of masonry walls. (Ref. 12)

EXFILTRATION - The uncontrolled movement of air from the house interior to the outdoors through cracks in the building envelope. (see INFILTRATION)

FROST HEAVE - The movement of soil caused by the expansion of water as it freezes.

GABLE - The upper triangular-shaped portion of the end wall of a house. (Ref. 12)

HEADER - A wood member at right angles to a series of joists or rafters at which the joists or rafters terminate.

HILP - Home Insulation Loan Program.

HOTCAN - A computer program designed to analyize and predict the space heating loads of houses.

HEAT RECOVERY VENTILATOR - A mechanical device designed to exhaust stale air from a house and simultaneously introduce fresh air while using the exhaust air to preheat the incoming fresh air.

HYDRONIC HEATING - A heating system in which water is used to transfer heat from the heating plant to the individual rooms.

ICE DAM - An ice obstruction which forms on a roof, usually near the eaves, that prevents proper drainage of water off the roof thus creating a pool of water which can penetrate under the roof membrane and cause damage to underlying decking, insulation, etc.

INFILTRATION - The uncontrolled movement of air from the outdoors into the house interior through cracks in the building envelope. (see EXFILTRATION)

KNEEWALL - Partitions of varying length used to support roof rafters when the span is so great that additional support is required to stiffen them. (Ref. 12)

PLATE - The horizontal member attached to the ends of the studs. Also called top or bottom plates, depending on their location. (Ref. 12)

PLATFORM FRAME CONSTRUCTION - A method of wood frame construction in which floor joists of each storey rest on the top plates of the storey below. (Ref. 11) (see BALLOON FRAME CONSTRUCTION)

RRAP - Residential Rehabilitation Assistance Program.

RSI - A metric measure of the thermal resistance of a material or assembly.

SILL PLATE - A structural member anchored to the top of a foundation wall, upon which the floor joists rest. (Ref. 12)

SLAB-ON-GRADE - A form of construction in which the concrete floor slab is poured directly on grade with little, if any, excavation.

SOFFIT - The underside of a roof overhang.

TRUSS - A framework composed of a series of members connected together to act as a single structural assembly.

UFFI - Urea formaldehyde foam insulation.